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MATHEMATICS.—*A note on values of a quadratic form.* M. MARCUS,[1] National Bureau of Standards and University of British Columbia. (Communicated by O. Taussky-Todd.)

(Received March 13, 1957)

If A is an Hermitian n-square complex matrix then the multiplicity l of an eigenvalue λ is the dimension of the null-space $N(\lambda)$ of $\lambda I - A$. $N(\lambda)$ is the set of vectors x for which $(\lambda I - A)x = 0$. It is clear that $x \in N(\lambda)$ implies

$$(Ax, x) = \lambda \tag{1}$$

and the maximum number of orthonormal (o.n.) solutions in $N(\lambda)$ to the equation (1) is of course l. However, if $x \notin N(\lambda)$ then it is still possible for (1) to be satisfied. The problem then arises: for α in the *field of values of* A determine the largest integer p for which there exist p o.n. solutions x of the equation

$$(Ax, x) = \alpha, \tag{2}$$

and exhibit the vectors x satisfying (2). We denote this maximal p by $m(\alpha)$. We recall that the field of values of a matrix A is the image of the unitsphere $\| x \| = 1$ under the mapping $x \to (Ax, x)$. It is a classical theorem of Hausdorff that the field is convex and hence for an Hermitian matrix it is the closed interval with endpoints the largest and smallest eigenvalues (for an account of this see, e.g. [4]).

Let $\lambda_1 \geq \cdots \geq \lambda_n$ be the eigenvalues of A and let

$$c_k = \frac{1}{k}\sum_{j=1}^{k} \lambda_{n-j+1}, \qquad d_k = \frac{1}{k}\sum_{j=1}^{k} \lambda_j$$

for $k = 1, \cdots, n$. Let I_k be the closed interval $[c_k, d_k]$ and let γ_k be the characteristic function of I_k. Clearly from the ordering of the λ_j it follows that $c_k \leq c_{k+1} \leq d_{k+1} \leq d_k$. This implies that

$$I_{k+1} \subseteq I_k \qquad k = 1, \cdots, n-1$$

Theorem 1.

$$m(\alpha) = \sum_{j=1}^{n} \gamma_j(\alpha).$$

Proof. We show first that for $\alpha \in I_k$ the number $m(\alpha) \geq k$ by exhibiting a set of k o.n. vectors z_r for which $(Az_r, z_r) = \alpha$. First we consider the case when the two sets of numbers $\lambda_1, \cdots, \lambda_k$ and $\lambda_n, \cdots, \lambda_{n-k+1}$ overlap in $\lambda_s, \cdots, \lambda_k$ where $s = n - k + 1$. Since A is Hermitian choose an o.n. set of eigenvectors u_j such that

$$Au_j = \lambda_j u_j \quad j = 1, \cdots, n.$$

For $t \in [0, 1]$ define the vectors

$$z_r(t) = \frac{1}{\sqrt{k}}\left\{\sum_{j=0}^{k-s} \theta^{r(k-j)} u_{k-j} + \sqrt{t}\sum_{j=1}^{s-1} \theta^{rj} u_j + \sqrt{1-t}\sum_{j=1}^{n-k} \theta^{rj} u_{n-j+1}\right\} \quad r = 1, \cdots, k$$

where θ is a primitive kth root of unity. Now,

$$k(z_r(t), z_m(t)) = \left(\sum_{j=0}^{k-s} \theta^{r(k-j)} u_{k-j}, \sum_{j=0}^{k-s} \theta^{m(k-j)} u_{k-j}\right)$$

[1] This work was completed under a National Research Council–National Bureau of Standards Postdoctoral Research Associateship.

$$+ t\left(\sum_{j=1}^{s-1}\theta^{rj}u_j, \sum_{j=1}^{s-1}\theta^{mj}u_j\right)$$

$$+ (1-t)\left(\sum_{j=1}^{n-k}\theta^{rj}u_{n-j+1}, \sum_{j=1}^{n-k}\theta^{mj}u_{n-j+1}\right)$$

$$= \sum_{j=0}^{k-s}\theta^{(r-m)(k-j)} + t\sum_{j=1}^{s-1}\theta^{(r-m)j}$$

$$+ (1-t)\sum_{j=1}^{n-k}\theta^{(r-m)j}$$

Since $n - k = s - 1$

$$k(z_r(t), z_m(t)) = \sum_{j=0}^{k-s}\theta^{(r-m)(k-j)} + \sum_{j=1}^{n-k}\theta^{(r-m)j}$$

$$= \sum_{j=1}^{k-}\theta^{(r-m)j}$$

But $r - m \not\equiv 0 \pmod{k}$ unless $r = m$ and thus $(z_r(t), z_m(t)) = \delta_{rm}$. Now set

$$\varphi_r(t) = (Az_r(t), z_r(t))$$

and compute that

$$\varphi_r(t) = \frac{1}{k}\left\{\left(\sum_{j=0}^{k-s}\theta^{r(k-j)}\lambda_{k-j}u_{k-j}, \sum_{j=0}^{k-s}\theta^{r(k-j)}u_{k-j}\right)\right.$$

$$+ t\left(\sum_{j=1}^{s-1}\theta^{rj}\lambda_j u_j, \sum_{j=1}^{s-1}\theta^{rj}u_j\right)$$

$$+ (1-t)\left(\sum_{j=1}^{n-k}\theta^{rj}\lambda_{n-j+1}u_{n-j+1},\right.$$

$$\left.\left.\sum_{j=1}^{n-k}\theta^{rj}u_{n-j+1}\right)\right\}$$

$$= \frac{1}{k}\left\{\sum_{j=0}^{k-s}\lambda_{k-j} + t\sum_{j=1}^{s-1}\lambda_j + (1-t)\right.$$

$$\left.\cdot\sum_{j=1}^{n-k}\lambda_{n-j+1}\right\}.$$

Thus

$$\varphi_1(t) = \cdots = \varphi_k(t)$$

and we check that

$$\varphi_j(0) = c_k, \qquad \varphi_j(1) = d_k;$$

thus for some $t_0 \in [0, 1]$

$$\varphi_j(t_0) = \alpha \qquad j = 1, \cdots, k$$

and $m(\alpha) \geq k$. On the other hand, suppose $\alpha \in I_k - I_{k+1}$ and $m(\alpha) = k + p$, $p \geq 1$. Then there exist $k + p$ o.n. vectors x_j for which

$$(Ax_j, x_j) = \alpha \qquad j = 1, \cdots, k + p.$$

Summing on j we have

$$\alpha = \frac{1}{k+p}\sum_{j=1}^{k+p}(Ax_j, x_j).$$

A result of K. Fan [2] states that

$$\sum_{j=1}^{k+p}(Ax_j, x_j)$$

is a point in I_{k+p}. It follows that

$$c_{k+1} \leq c_{k+2} \leq \cdots \leq c_{k+p}$$

$$= \frac{1}{k+p}\sum_{j=1}^{k+p}\lambda_{n-j+1} \leq \alpha \leq \frac{1}{k+p}\sum_{j=1}^{k+p}\lambda_j$$

$$= d_{k+p} \leq \cdots \leq d_{k+1}$$

and hence that $\alpha \in I_{k+1}$. Now, in case $\lambda_1, \cdots, \lambda_k$ and $\lambda_n, \cdots, \lambda_{n-k+1}$ do not overlap, the situation is considerably simpler. Define

$$z_r(t) = \frac{1}{\sqrt{k}}\left\{\sqrt{t}\sum_{j=1}^{k}\theta^{rj}u_j\right.$$

$$\left. + \sqrt{1-t}\sum_{j=1}^{k}\theta^{rj}u_{n-j+1}\right\}$$

and again note that $z_1, \cdots, z_k$ form an orthonormal set and also that

$$\varphi_r(t) = (Az_r(t), z_r(t))$$

$$= \frac{1}{k}\left\{t\sum_{j=1}^{k}\lambda_j + (1-t)\sum_{j=1}^{k}\lambda_{n-j+1}\right\}.$$

The argument then proceeds as above. This completes the proof.

A set that arises often in computing extreme values of a function of Hermitian quadratic forms is the convex hull $H(\lambda)$ of the points $P\lambda$ where $\lambda = (\lambda_1, \cdots, \lambda_n)$ and P runs over all n-square permutation matrices (see [1], [3]). For $\alpha \in I_1$ let $l(\alpha)$ be the largest p for which there exists a point $a \in H(\lambda)$ with p coordinates equal to

α. Then Theorem 1 has the following geometric interpretation:

Theorem 2.

$$l(\alpha) = m(\alpha).$$

Proof. Suppose $m(\alpha) = k$ and choose o.n. $x_j j = 1, \cdots, n$ for which

$$A_j = (Ax_j, x_j) = \alpha \qquad j = 1, \cdots, k$$

$$A_{k+p} \neq \alpha \qquad p = 1, \cdots, n - k.$$

Then define $K(\lambda)$ to be the convex intersection of the half spaces

$$\sum_{j=1}^{r} t_{i_j} \leq \sum_{j=1}^{r} \lambda_j \qquad (3)$$

$$1 \leq r \leq n - 1,$$

$$1 \leq i_1 < \cdots < i_r \leq n$$

and the hyperplane

$$\sum_{j=1}^{n} t_j = \sum_{j=1}^{n} \lambda_j. \qquad (4)$$

It is known [3] that $H(\lambda) = K(\lambda)$. By the cited result of Fan,

$$a = (A_1, \cdots, A_n)' \in K(\lambda)$$

and hence $a \in H(\lambda)$. Thus $l(\alpha) \geq k$. On the other hand suppose that for some $b = (b_1, \cdots, b_n) \in H(\lambda)$, the point b has $k + p$ coordinates equal to α, $p \geq 1$. Then since $b \in K(\lambda)$ it follows from [3; Theorem 4] that $b = Q\lambda$ where $Q_{ij} = |U_{ij}|^2$ and $(U_{ij}) = U$ is a unitary n-square matrix. But then

$$b_r = \sum_{j=1}^{n} |U_{rj}|^2 \lambda_j.$$

Now let V be unitary satisfying $V^*AV = \operatorname{diag}(\lambda_1, \cdots, \lambda_n) = D$, and let U_r be the rth row vector of U. Then

$$b_r = (DU_r, U_r) = (V^*AVU_r, U_r)$$

$$= (AVU_r, VU_r) = (Az_r, z_r),$$

where $z_r = VU_r r = 1, \cdots, n$ form an o.n. set. Since $b_r = \alpha$ for $k + p$ values of r, then $m(\alpha) \geq k + p$. This contradiction completes the proof.

We remark that Theorem 2 is easily restated as follows: *There exists a solution of the system (3) and (4) with k coordinates equal to α if and only if*

$$\sum_{j=1}^{n} \gamma_j(\alpha) \geq k.$$

Actually, Dr. E. Haynsworth has pointed out that this result can be obtained directly from the system (3) and (4) and hence by Horn's result, Theorem 1 above follows. However, this method does not exhibit explicitly the vectors we have called $z_r(t)$.

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(4) PARKER, W. V. *Sets of complex numbers associated with a matrix.* Duke Math. Journ. **15:** 711–715. 1948.

JUNIOR ACADEMY EXCURSION

Under the auspices of the Washington Junior Academy of Sciences, 1,049 teen-agers came to Philadelphia on Saturday, December 8, on a special 17-car train, to spend a scientific day visiting the Museum and the Planetarium of The Franklin Institute and also the Academy of Natural Sciences. An overflow of 1,137 who could not be accommodated on the first trip, followed the same procedures on Saturday, December 15.

Railroad officials report this to be the largest student group ever transported by rail from that vicinity. The first such trip was taken from Washington in 1954, when 60 members of the Academy and their sponsors came to Philadelphia. Last year's one-day trip to New York, numbering 560, was no adequate preparation for the enthusiastic response for this year's trip to Philadelphia.—*The* [Franklin] *Institute News*, Feb. 1957.

PHYSIOLOGY.—*On the quantum efficiency of scotopic and photopic vision.*[1] R. CLARK JONES, Research Laboratory, Polaroid Corporation, Cambridge, Mass. (Communicated by A. M. Stone.)

(Received September 28, 1956

Before beginning the discussion of the technical part of this material, I should like to express my very sincere appreciation to the Washington Academy of Sciences for inviting me to take part in this symposium. It is truly a privilege to share the platform with such distinguished participants.

I should like to begin with the "quantum efficiency of vision." When anyone uses this term, the first thing that most people think about is the quantum efficiency at the threshold of vision of the dark-adapted eye. This is the quantum efficiency that Dr. Baumgardt was discussing during most of his talk. It is the quantum efficiency that Hecht talked about in his Ives' Medal address[2] in 1941.

But I am concerned now exclusively with the quantum efficiency of the visual process at adaptation levels that are above the dark-adapted threshold. In fact, I shall refer to it as a function of the adaptation level of the eye. I am concerned also with adaptation levels that cover a fairly wide range: from one-millionth of a foot-lambert or millilambert—they're about the same—up to 1,000 foot-lamberts. The kind of quantum efficiency I shall be talking about is that which was given this name by Dr. Albert Rose[3] of RCA.

The intuitive idea of quantum efficiency is quite simple. We simply ask, at any given adaptation level, what fraction of the light that enters the eye effectively participates in the visual process—that is to say, what fraction effectively contributes to the response of the eye and brain combination. For example, of every 100 photons that enter the eye, perhaps only 10 are absorbed by the visual pigments; perhaps only 5 participate in the actual response of that rod or cone, and perhaps only 2 actually succeed in getting through the torturous nerve pathways into the interpretive centers of the brain. If the number be 2, then we should say that the over-all quantum efficiency of vision is 2 percent. Now, as you seek the quantum efficiency defined in this way is a kind of utilization factor that tells what fraction of the light incident on the entrance pupil of the eye is actually used in the over-all visual process. Nothing more than just that should be read into it.

The quantum efficiency I am talking about has no necessary connection whatever with the quantum efficiency of the photochemical processes that go on in the receptor cells. Because of this possible source of confusion, some of my friends feel that the term quantum efficiency is a bad term and that I should use some other term, such as utilization factor or quantum utilization factor. But I am going to continue to use this term, quantum efficiency, not only because I am used to it and would find it difficult to change, but also because it is already in the literature in this sense.

Now it is an unfortunate fact, or perhaps fortunate, that there is no direct way of measuring the quantum efficiency of the visual process. Perhaps some day, when we know a lot more about the function of the eye and the function of the nervous system, we shall be able to make an educated guess as to what the over-all efficiency is. But in the meantime we are forced to make use of indirect methods. These consist of comparing the actual performance of the eye with the computed performance of an ideal image evaluating system, either an ideal contrast perceiving device or an ideal flicker perceiving device. We compare the computed performance of an ideal device that makes use

[1] Paper presented before the Washington Academy of Science on May 17, 1956, as a part of a Symposium on the Quantum Relationships in vision.

[2] HECHT, SELIG, *The quantum relations of vision*, Journ. Opt. Soc. Amer. **32:** 42–49. 1942.

[3] ROSE, ALBERT, *Sensitivity performance of the human eye on an absolute scale*, Journ. Opt. Soc. Amer. **38:** 196–208. 1948; *A unified approach to the performance of photographic film, television pickup tubes, and the human eye*, Journ. Soc. Mot. Piet. Eng. **47:** 273–294. 1946; *Television pickup tubes and the problem of vision*, Adv. Electronics **1:** 131–166. 1948.

of every incident quantum, with the actual performance of the human eye.

My notes say that there are two kinds of performance of the human eye that have been studied for their relevance to the quantum efficiency of vision. The first is contrast perception and the second is flicker perception. And now after hearing Dr. Hartline's talk, I feel we have to add a third—the procedures used by him. There's a great deal involved in what Dr. Hartline called the quantum hypothesis. But one part of it—the one that he used in discussing the way that the slopes vary as the state of light adaptation varies—this part of the quantum hypothesis is that the quantum efficiency, as I defined it, is a constant. I believe that you will agree with that, Dr. Hartline.

(Dr. Hartline nodded assent.)

So far as I know the first suggestion that quantum fluctuations (the statistics of the quanta that reach the eye)—the first suggestion that these quantum fluctuations might limit the contrast perception of the eye—was due to Barnes and Czerny,[4] in 1932. They mention the idea only qualitatively. The idea was first given quantitative form, I think, by De Vries[5] in 1943, but the full power of the method awaited the classic work of Rose in 1946 and 1948. So far as I know there have been no published results on the use of flicker perception to determine the quantum efficiency of vision. I did a little work on the subject in 1954, and during the last few weeks I have made a few more measurements.

Now, I should like to present a more explicit idea of just how one computes the quantum efficiency from information on the performance of the eye. In Table 1 we measure the ability of the eye to perceive contrast in a small spot $\frac{1}{4}°$ in diameter with the adapting field at a brightness of $\frac{1}{10}$ of a foot-lambert. Now, experimentally, according to Blackwell's results the eye can see with 90 percent probability a contrast of 2.2 percent—i.e., if this $\frac{1}{4}°$ spot is brighter than the adapting field by 2.2 percent it can be seen by the average observer 90 percent of the time. It is easy to compute that such a source delivers to the eye 400,000 photons every second, and information I will present later will suggest that the integration time of the eye is about 62 milliseconds at this adaptation level. From this we conclude that the number of photons that reach the eye every integration period is about 25,000 under these conditions.

Let us now introduce the important and very well-founded idea that the arrival of each quantum is an independent event—that is to say that its arrival time is statistically independent of the arrival time of all the other photons. It follows that the statistical distribution of the number of photons that arrive in successive integration periods is a Poisson distribution. A Poisson distribution has the important property that the root mean square fluctuation in the number is proportional to the square root of the number of events. Thus we find that the root mean square fluctuation in successive integration periods is 158 photons, which is a fluctuation of 0.635 percent.

Right here we reach the heart of the calculation. Since the actual amount of light that reaches the eye during successive periods is varying by a root-mean-square amplitude of about 0.6 percent, it is clear that even an ideal device that makes use of every one of these 400,000 photons per second would be unable to discriminate a contrast difference less than this amount. These fluctuations constitute a kind of noise, and it is a well-known fact that one can not discriminate a signal that is less than the root-mean-square amplitude of the noise. I shall now make this assumption specifically—i.e., I assume that if we did have an ideal device with 100 percent quantum efficiency then the contrast threshold of this ideal device would be about 0.6 percent. But now you see experimentally, the contrast threshold of the eye is not 0.6 percent but is 2.2 percent.

How can we understand this fact? We can very easily understand this discrepancy if we suppose that the eye does not have a quantum efficiency of 100 percent but instead has a lesser quantum efficiency. If we assume provisionally, as in the lower part of Table 1, that the quantum efficiency is

[4] BARNES, R. B., AND CZERNY, M., *Observation with the eye of a Schrot effect for photons*, Zeitschr. für Physik **79:** 436–449. 1932.

[5] DE VRIES, HL., *The quantum character of light and its bearing upon threshold of vision, the differential sensitivity and visual activity of the eye*, Physica **10:** 553–564. 1943.

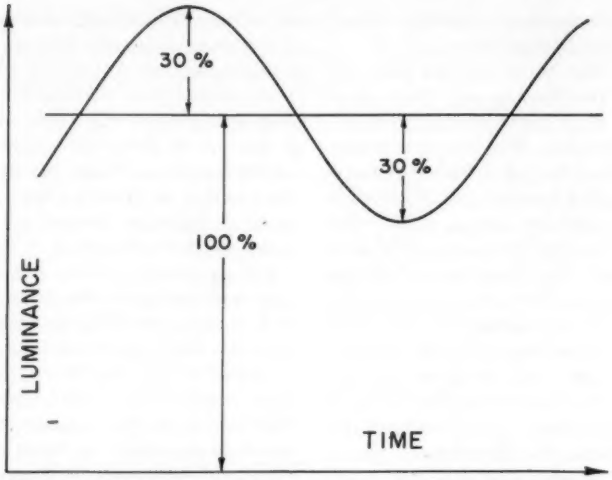

FIG. 1.—Curve showing the luminance as a function of the time for a sinusoidally modulated target. The index of modulation is 30 percent.

8 percent—i.e., that the eye makes use of 8 percent of these 400,000 photons every second, then the number in each integration period is about 2,000 and the square root of this is about 44, which is 2.2 percent of this number. And so we see that if we do assume that the number used is only 8 percent of the number available we compute a performance of the eye which is in accord with the experimental threshold. Thus by comparing the performance of an ideal device with the actual performance of the eye we find that the eye behaves as though it uses effectively 8 percent of the incident light—that is, an overall quantum efficiency of 8 percent under these conditions.

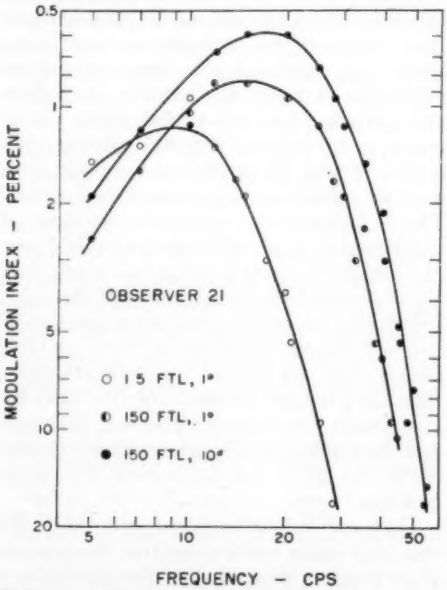

FIG. 2.—The threshold modulation index in percent plotted versus the modulation frequency for three different combinations of adapting luminance and target diameter, for one observer.

We can also get at the quantum efficiency of vision through flicker perception. But first let me define the index of modulation of a flickering source of light. Figure 1 shows how the luminance varies with the time in a sinusoidally modulated light source. In this plot the luminance rises 30 percent above its mean value and then falls to 30 percent below. This amount we call the index of modulation, or modulation index—i.e., for a source that follows that curve, the modulation index is 30 percent. Obviously, the maximum possible modulation index is 100 percent. Figure 2 shows some experimental results obtained in 1954. Figure 2 is for a young man whose age was 21. (We did not have 21 observers!) The three curves in the plot are for three different measuring conditions. The top curve is for a 10° source with a mean luminance of 150 foot-lamberts. This is quite a big source and quite a high lumin-

ance. The middle curve is for a source diameter of only 1° but still for 150 foot-lamberts. And in the bottom curve the source diameter is still 1°, but the luminance has dropped to 1.5 foot-lamberts. The maximum of the top curve corresponds to a threshold modulation index of only 0.6 percent and this occurs at a modulation frequency of about 18 cycles.

The measurements we made in 1954 had a very limited objective. At that time I was interested merely in trying to get some information on the band-width of the eye and had no intention of trying to compute quantum efficiency from the results. For that reason the measurements were made with a very limited range of luminance and with flicker targets of excessive angular diameter.

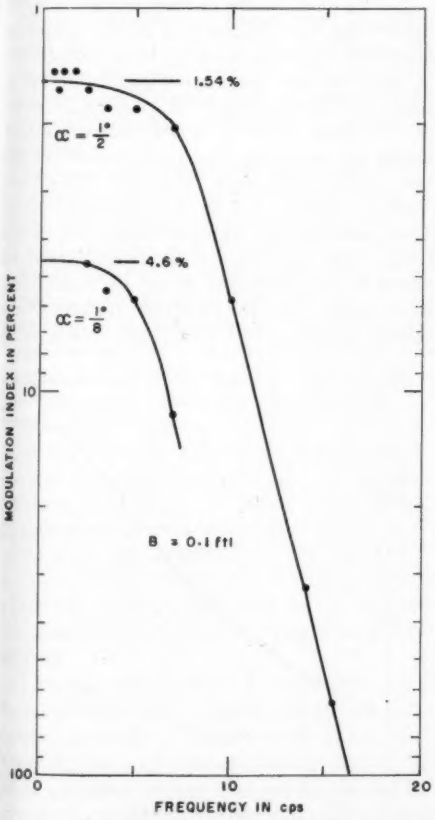

FIG. 3.—The threshold modulation index in percent plotted versus the modulation frequency for two target diameters at an adapting luminance of 0.1 foot-lambert, for one observer.

In the past few weeks I have been making a set of measurements over a wide range of luminance, and with target angular diameters in the range where I anticipated that the quantum efficiency would be a maximum. Figure 3 shows a sample of my results. The pair of curves was measured at an adapting level of $\frac{1}{15}$ foot-lambert, but with a flicker spot luminance of $\frac{1}{10}$ foot-lambert. The upper curve is for a spot diameter of $\frac{1}{2}°$, and the lower curve for a spot diameter of $\frac{1}{8}°$. Both of the curves correspond to about the same quantum efficiency. The threshold indicated here corresponds to a probability of detection of roughly 90 percent.

We shall now compute the quantum efficiency indicated by the upper curve. The upper curve is the one we used to determine the integration time of the eye at $\frac{1}{10}$ foot-lambert—this curve has a bandwidth of about 8 cycles per second, which corresponds to an integration time of about 62 milliseconds. Note also that the threshold modulation index of the flat, low-frequency, portion is about 1.54 percent: this corresponds to an rms fluctuation of 1.09 percent.

Just as before, we compute in Table 2 the number of quanta that enter the eye each second from the test spot of $\frac{1}{2}°$ diameter, and find it to be 1,670,000 quanta per second, which in the integration time of 62 milliseconds becomes 86,500, whose square root is 294 photons, which corresponds to a fluctuation of 0.34 percent.

Again, if the eye had a quantum efficiency of 100 percent, we might expect that the threshold modulation index would be 0.34 percent. But the experimental threshold is much higher, having an rms value of 1.09 percent. This comparison corresponds to a quantum efficiency of about 10 percent, and to prove this we note that 10 percent of the 86,500 photons in an integration period is 8,650, whose square root is 93 photons, which corresponds to 1.07 percent of the 15,600. Thus we have proved that the observed flicker threshold corresponds to a quantum efficiency of about 10 percent.

If we compare the threshold indicated by

TABLE 1

Source: ¼°, 0.1 ft-lamb
C_{90} = 2.2 percent (exp)

R = 400,000 photons/sec
N = 24,800 photons in 62 msec
ΔN = 158 photons = 0.64 percent of N

If Q = 8 percent, N = 1980 photons
ΔN = 44.5 photons = 2.2 percent of N

C_{90} = 2.2 percent
(calc for Q = 8 percent)

Blackwell's contrast data in Table 1 with the result indicated by my flicker data in Table 2, we have 8 percent efficiency compared with 10 percent. In this business, that is very good agreement.

Now my 1956 flicker measurements are still in a preliminary state. We still have a number of calibration refinements to carry out, and so far we have data on only one observer, namely my right eye. But preliminary as they are, they do serve to show quite well the way that the bandwidth of the eye varies with adaptation level.

TABLE 2

Source: ½°, 0.1 ft-lamb
$m_{90,\,\mathrm{rms}}$ = 1.09 percent (exp)

R = 1,670,000 photons/sec
N = 86,500 photons in 62 msec
ΔN = 294 = 0.34 percent of N

If Q = 10 percent, N = 8,650 photons
ΔN = 93 photons = 1.07 percent of N

$m_{90,\,\mathrm{rms}}$ = 1.07 percent
(calc for Q = 10 percent)

Figure 4 shows the frequency bandwidths indicated by my frequency measurements. The ordinate is the frequency bandwidth on a logarithmic scale, and the abscissa is the logarithm of the luminance in foot-lamberts. You will note that the bandwidth varies from 3.2 cps at very low luminances up to 16 cps at very high luminances. This corresponds to a range of integration time from 156 milliseconds down to 31 milliseconds. At one tenth of a foot-lambert you see from the curve that the bandwidth is 8 cycles per second, which corresponds to an integration time of 62 milliseconds, as used in Tables 1 and 2.

Now let us go back to the computation of the quantum efficiency from data on the performance of the eye. If we take the computational procedure outlined in Tables 1 and 2 and put it in the form of equations, we find the following equations:

Contrast Perception

$$Q_{\%} = 0.765 \frac{k^2 \Delta f_{\mathrm{cps}}}{\alpha^2_{\mathrm{deg}} C^2_{\%} B_{\mathrm{ftl}} D^2_{\mathrm{mm}} S} \qquad (1)$$

Flicker Perception

$$Q_{\%} = 1.53 \frac{k^2 \Delta f_{\mathrm{cps}}}{\alpha^2_{\mathrm{deg}} m^2_{\%} B_{\mathrm{ftl}} D^2_{\mathrm{mm}} S} \qquad (2)$$

These equations differ only in the numerical constant and in the substitution of m for C in the lower equation. In fact, if $\frac{1}{2}m^2 = C^2$, the two equations are identical.

Let us look at one of these equations; the upper one, for example. Q is the quantum efficiency we are seeking. Δf is the bandwidth of the eye, and data on this are shown in Figure 4. The angle α is the angular diameter of the spot, and C is the corresponding threshold contrast. The performance of the eye enters primarily through these two factors, α and C. B is the adapting luminance, and D is the pupillary diameter. S is a factor that corrects for the Stiles-Crawford effect in the photopic range of luminance. S is unity for the scotopic range. Very adequate data on D and S are available in

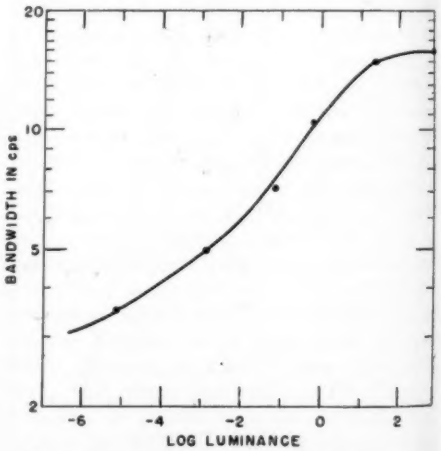

FIG. 4.—The effective bandwidth in cycles per second plotted versus the adapting luminance in foot-lamberts.

the literature; they both depend on the adapting luminance, and plots of them will be shown on a later slide.

The factor k I have left till last; k is the threshold signal-to-noise ratio of the visual process. This factor k is the most uncertain factor in this equation, and is the weakest link in our computation of the quantum efficiency. Unfortunately, k occurs squared. Rose assumed that k was 3, whereas I used k equal to 1 in the computations carried out in the earlier slides. So far, no adequate measurement of the factor k have been made; it is necessary to assume a plausible value. In summary, the uncertainty in the value of k is the chief weakness of the indirect method of evaluating the quantum efficiency of vision.

These equations indicate that we must have data on α and C to determine the quantum efficiency by the first equation, and we must have data on α and m to determine the quantum efficiency by the second equation.

Fortunately, Blackwell[6] has provided us with abundant data on the relation between the target diameter α, the adapting luminance B, and the contrast threshold C_{90}. Figure 5 shows Blackwell's data in the form of the product αC_{90} plotted against the target diameter. The separate curves are for different values of the adapting luminance. The square of this product enters downstairs in the formula for the quantum efficiency.

Let us look specifically at the fifth curve from the bottom. This curve is for a luminance of $\frac{1}{10}$ foot-lambert. The αC product for this curve has a minimum value of 0.55 degree-percent for a target diameter of $\frac{2}{10}°$; these were the numerical values we used in Table 1. At this adapting level, the quantum efficiency of vision is highest for a $\frac{2}{10}°$ target diameter, and is less for larger or smaller targets.

The top curve is for a luminance 1,000 foot-lamberts, and it has its minimum for a target diameter slightly more than $\frac{1}{10}°$. This diameter is just about the size of the small ganglion cells mentioned by Dr. Baumgardt. In contrast with this, the lowest curve, for a luminance of 10^{-5} foot-lambert, has its minimum value for a target diameter of slightly over 1°, which is very close to the 70′ diameter of the giant ganglion cells. It is interesting that the diameter of these two cells appears so clearly in Blackwell's raw data on the performance of the eye.

From each of the separate curves, I have picked off the minimum value of αC, and in Figure 6 the minimum value of αC is plotted versus the adapting luminance in the lower curve. Unlike Figure 5, the αC product is here plotted on a right-side-up logarithmic scale.

In Figure 6 we meet one of the complexities of the situation. Blackwell, in his report on the work of the Tiffany Foundation, did not present just one complete set of data but rather three complete sets of data.

In the upper curve we have the results given in Part I of Blackwell's report. For these data the subjects had 6 seconds to determine in which of eight positions the target was located. Six seconds, however, is not long enough to yield a minimum contrast threshold; Blackwell remarks that not even 60 seconds is long enough.

The lower curve in Figure 6 corresponds to the data shown in Figure 5, from Part III of the report, and for these data the subjects had 15 seconds to determine merely the presence or absence of the target. The lower curve indicates lower contrast thresholds, much lower in the photopic range. The difference between the two curves corresponds to a difference in quantum efficiency by a factor of nearly 20.

The upper curve is the one used by Rose in his publications, and as we shall see it yields a quantum efficiency nearly independent of the adapting luminance. But the upper curve does not correspond to minimum thresholds, and it seems to me that the lower curve is the one that should be used to compute the quantum efficiency.

The six points indicated by open circles in Figure 6 show the values of 0.7 of the aperture diameter-threshold modulation index product as determined from the flicker threshold measurements on my right eye. The agreement with the lower curve is quite striking, except for the point at the low luminance of 10^{-5} foot-lambert. The point

[6] BLACKWELL, H. R., *Contrast thresholds of the human eye*, Journ. Opt. Soc. Amer. **36**: 624–643. 1946.

at 1/10 foot-lambert represents the information used in the calculation in Table 2. The open circles, representing flicker measurements made by me, are in definite disagreement with the upper curve but are in good agreement with the lower curve.

In Figure 7 we have plots of the various parameters that enter into Eq. (1) for the quantum efficiency. We see a plot of the bandwidth Δf, of the luminance B, of the D^2S product, and the square of the αC product, all plotted as a function of the luminance B. The ordinate coordinate scale is different for each of the four types of curves i.e., the relative position vertically of the various curves has no significance. By comparing the slopes of the various curves, you can see the relative importance of the various factors in contributing to changes in the quantum efficiency as the adapting luminance is changed. The two nearly horizontal curves are the bandwidth, which varies only over the range from 3.2 to 16 cps, and the square of effective pupillary diameter, which varies over the range from 64 to 3.5 square millimeters.

The two factors that do change by many orders of magnitude over the billion to one range of adapting luminance are the square of the αC product, and the luminance itself. As you see these two factors have slopes that are nearly equal and opposite so that, roughly speaking, the variation in these two factors tends to cancel out in the formula (1) for the efficiency.

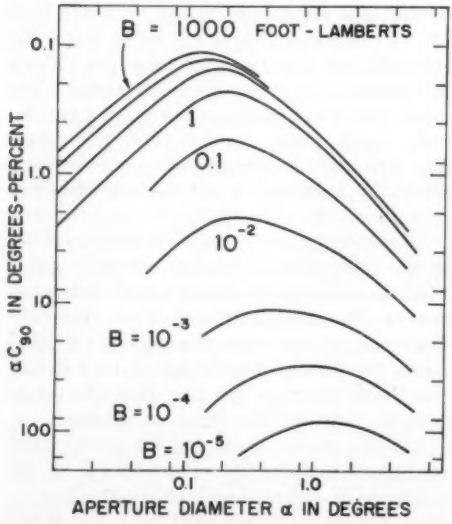

FIG. 5.—The threshold diameter-contrast product in degrees-percent plotted versus the target diameter in degrees. The several curves are for different adapting luminances. The curves are based on Blackwell's data.

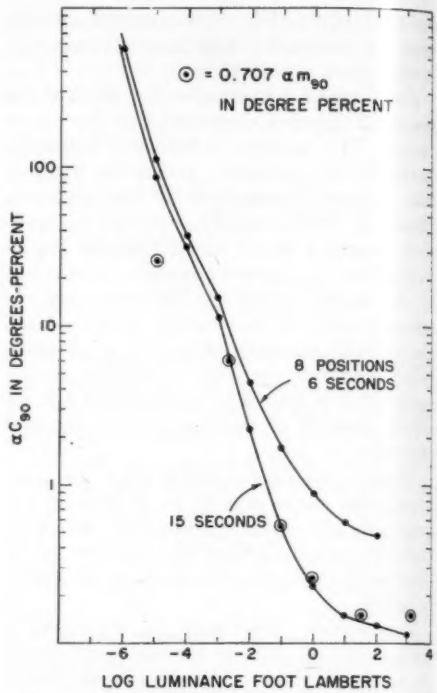

FIG. 6.—Curve showing the minimum threshold diameter-contrast product at each adapting luminance, plotted versus the adapting luminance. The distinction between the two curves is explained in the text. The circles are 0.707 times the threshold diameter-modulation index product based on the writer's flicker measurements.

Figure 8 shows the quantum efficiency of vision, as computed from the data shown in Figure 7. The upper curve shows the quantum efficiency computed from Blackwell's 15 second data, whereas the middle curve is computed from Blackwell's 8 position, six second data. The bottom curve is computed using Rose's assumption that the bandwidth is 2.5 cps at all adaptation levels. You will note that this bottom curve is remarkably flat. Between 10^{-6} and 1 foot-

lambert, the bottom curve varies less than any of the factors that enter into the formula.

But the flicker data show pretty clearly that the bandwidths are greater than 2.5 cps, particularly at photopic luminances, and the 15 second Blackwell data seem to me to be the most relevant data for the purpose of computing the quantum efficiency. Thus, in my opinion, it is the top curve that is most significant.

All these curves are computed with the parameter k taken equal to unity. It seems to me that this is the lowest value of k that makes sense at all. It is hard to see how the eye could detect a signal that has less amplitude than the noise, particularly since the eye can scarcely see this noise, if it can see it at all.

As mentioned before, Rose used a much larger value of k, a value that gave quantum efficiencies larger by a factor of ten. But this larger value of k seems unacceptable since the upper curve would then predict unbelievably large values of quantum efficiency—values very close to 100 percent.

Figure 8 is the chief result of this talk, and I give it considerable attention. The most striking thing about all of these three curves is the fact that the quantum efficiency varies so little over this very wide range of adapting luminance.

Ever since Rose published his papers in the late forties, workers in vision have been impressed by the fact that the quantum efficiency remains high at relatively high luminance. Let us focus our attention on the value indicated by the upper curve at ten foot-lamberts. The value is 3.5 percent—i.e., at this high luminance, one out of every 30 photons that enter the pupil of the eye is actually contributing to the discrimination of contrast. If the eye did not use this many, the eye could not perform the contrast discrimination that it actually can perform at 10 foot-lamberts. Since the over-all utilization factor is 3.5 percent, it follows that the absorption factor of the visual pigments must be at least this value, and because of other imperfections of the eye, the absorption factor must be somewhat larger, perhaps 10 percent.

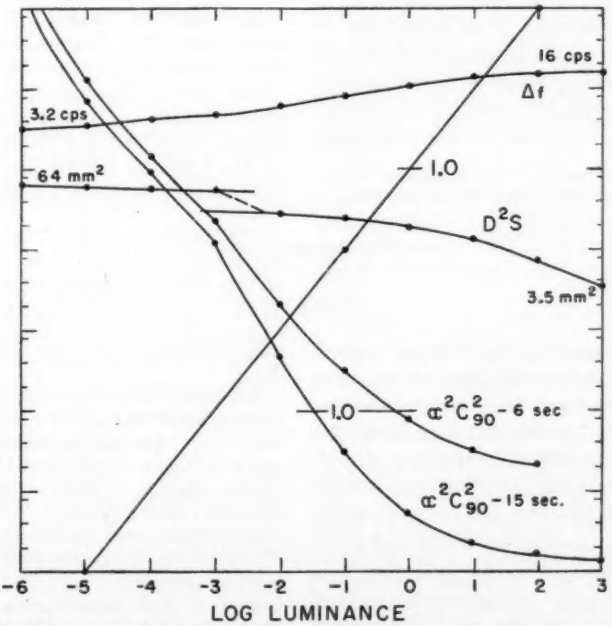

FIG. 7.—Four of the factors that occur in Eq. (1) plotted versus the adapting luminance in foot-lamberts.

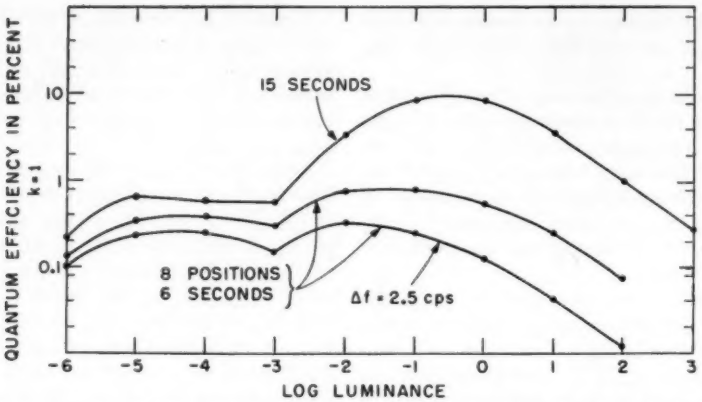

FIG. 8.—The quantum efficiency of human vision in per cent plotted against the adapting luminance in foot-lamberts. The upper curve is based on Blackwell's "one position, 15 second" data and on the bandwidths derived from the writer's flicker measurements. The middle curve is based on Blackwell's "8 position, 6 second" data and the writer's bandwidth data; the bottom curve is based on the same Blackwell data, and on Rose's assumption of a bandwidth that is independent of adapting luminance.

And now I join the two preceding speakers in driving nails in the coffin of the classical theory of dark adaptation. Let us note that at an adapting level of 10 foot-lamberts, the absolute threshold of the eye is more than 10,000 times the absolute threshold of a well dark-adapted eye.[7] If we should try to explain this large shift in absolute threshold by a corresponding change in the amount of absorbing material, we would be in violent conflict with the fact that the eye is actually absorbing about 10 percent of the incident light. Thus the quantum efficiency data in Fig. 8 preclude the possibility that light adaptation can be explained by any large change in the absorption coefficient of the retina, at least up 10 or 100 foot-lamberts.

If it has not already been clear, let me emphasize that the main contribution to what I have talked about has been made by Albert Rose. This talk has primarily been an exposition of Rose's procedure, supplemented with some additional information on the effective bandwidth of the eye that has resulted from my flicker measurements.

[7] BLANCHARD, JULIAN, *The brightness sensibility of the retina*, Phys. Rev. **11**: 81-99. 1918.

CHIGGERS

What are "chiggers"—the irritating pests of woods and brier patches that bore into the skins of man and other animals and engorge themselves with blood? They are only one stage in the life cycle of a tiny, spiderlike mite that goes through seven stages from egg to adult. They represent the only stage that is parasitic. Later ones are active and carnivorous, preying on insects and insect eggs. This is pointed out by Charles E. Farrell, of Vanderbilt University, in a systematic study of one genus of these creatures, the *Euschongastia*, common over much of North America, which has just been published by the Smithsonian Institution.

Relatively little has been known about the systematics of the pest in the past, but recently there has been a considerable awakening of interest. During World War II especially, there was an urgency to find out everything possible about the mites supposedly of the chigger family, which spread scrub typhus in the Pacific area. This interest, Mr. Farrell points out, has spread to other members of the group not necessarily concerned with transmission of any malady. Those mites which prey on man, however, always are suspect.

PHYSIOLOGY.—*The electrogram of the turtle heart in situ and after isolation.*[1]

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(Received January 22, 1957)

The durability of the turtle heart makes it suitable for a variety of physiological studies. Even after isolation the heart exhibits rhythmic beating for long periods of time. This hardiness has prompted investigators to use the isolated turtle heart in a variety of studies including hypothermia (Adolph, 1951), contractility (Katzung and Farah, 1956), and bioelectricity (Churney et al., 1948).

Izquierdo (1930) reported that excision of the frog's heart has a profound affect on heart rate. The heart rate at first accelerates, then decreases and finally, after approximately 25 minutes, reaches a steady state which approaches the heart rate *in situ*. With this in mind, it was decided to observe the effect of isolation of the turtle heart on heart rate. When preliminary studies indicated that a sharp decline in rate immediately followed excision, it was decided to pursue the study further and quantitatively study the effect of excision on the components of the electrogram.

MATERIAL AND METHODS

The turtle *Pseudemys elegans* was used for this investigation. The specimens were purchased from Carolina Biological Supply Co. and divided in three groups. Group A, consisting of seven turtles, was maintained at 18°–22° C and served as a control. Group B, consisting of 12 turtles, was refrigerated at 3° C. for 1 month, while Group C (12 turtles) was exposed to short-term hypothermia (colon temperature 4° C. for 2 minutes). The Group C specimens were then rapidly rewarmed, and electrograms recorded, *in situ* and after isolation.

Electrograms (electrocardiograms recorded directly from the heart surface) were obtained as follows: The animals were pithed, the carapace and pericardium removed, and an exploring electrode placed on the apex of the ventricle. The electrodes were made of 26-gauge silver wire mounted in glass tubing. The electrode tip was covered with blood-soaked cotton so that good contact was affected with no damage to the musculature. The indifferent electrode was in contact with a seared portion of the pubis.

This set-up is similar to the precordial lead IVF used on human beings (Hein and Reavis, 1950). The hearts were then isolated and transferred to Petri dishes containing amphibian Ringer's solution (room temperature) after the aortic trunk and the pre- and postcaval veins were ligated. Amphibian Ringer's solution consists of NaCl 6.5 gm, KCl 0.140 gm, $CaCl_2$ 0.120 gm, $NaHCO_3$ 0.200 gm, and H_2O 1000 ml (pH 7.65). The exploring electrode was, once again, placed on the ventricle apex (which was not submerged during recording), while the indifferent electrode was 2–3 inches away immersed in Ringer's solution. Isolation and recording was completed within two minutes.

A Grass Instrument Co. model IIIB electroencephalograph was used for recording the electrograms. Electrograms were studied and interpreted after standard measurements of the records were obtained.

RESULTS

Heart rate.—The results are summarized in Table 1. In all three groups there was a decrease in the mean heart rate upon excision. In the control group, the heart rate of five of the seven specimens decreased markedly upon isolation; it remained constant in the other two preparations. The change was from 34 to 23 beats/minute. Group B had a mean heart rate of 37 (after rewarming) which fell to 30 beats/minute after isolation. Group C had a mean rate of 29 (after rewarming), which fell to 25 beats/minute after isolation. Of the 31 specimens

[1] This work was accomplished under contract with the U. S. Air Force (# AF18(600)-364), Arctic Aeromedical Laboratory, Alaska. The splendid cooperation of Lt. Col. A. I. Karstens and his staff is gratefully acknowledged. George Kolacskovszky served as technical assistant and performed the tedious task of measuring the electrograms.

studied, the heart rate decreased immediately after isolation in 23 cases; it remained constant in four cases and increased in four cases.

Electrogram in situ.—The electrogram shown in Fig. 1a is typical of those recorded from the three groups. The P wave was upright in 17 specimens, diphasic in 7, negative in 5, and undiscernible in 2 specimens (Table 2). The upright QRS complex was in 24 instances, N-shaped, and slurred on the upstroke. It was rounded in four cases and notched in three.

The T wave was diphasic in all specimens. Twelve specimens had a +− type T wave (4 Group A, 5 Group B, and 3 Group C). The 19 −+ type T waves were distributed as follows: Group A, 3; Group B, 7; Group C, 9. In all other respects, the *in situ* electrograms of the three groups were similar.

Electrogram after isolation of heart.—The major effect of isolation of the heart on the P wave was the change in direction of the wave, especially in Groups B and C. These results are summarized in Table 2. The effect of isolation of the heart on the R wave shape was evident in all groups especially B and C. *In situ*, 24 specimens showed a normal, slurred upstroke of the QRS complex. After isolation, such a configuration was evident in only 15 specimens (3 in Group A, 8 in Group B, and 4 in Group C). The main change was in the rounding or notching of the upstroke of the QRS complex (Fig. 1b).

Note (Table 1) that the heart rate decline after isolation is due to changes in duration of ecg components other than the R wave. The P wave and Q-T interval increased in duration, substantially. The amplitude of the R wave was diminished.

TABLE 1.—HEART RATE AND DIMENSIONS OF THE ELECTROGRAM COMPONENTS RECORDED FROM THREE GROUPS OF TURTLE HEARTS, IN SITU AND AFTER ISOLATION

Group A, control; Group B, long-term hypothermia; Group C, short-term hypothermia.

	Group A		Group B		Group C	
	In situ	Isolated	In situ	Isolated	In situ	Isolated
Duration P, sec.	0.06	0.10	0.08	0.09	0.09	0.09
Duration P-R segment, sec.	0.27	0.37	0.37	0.37	0.56	0.48
Amplitude R, millivolts	4.3	2.5	4.1	2.4	6.0	3.1
Duration R, sec.	0.09	0.09	0.09	0.07	0.13	0.11
Duration Q-T interval, sec.	1.28	1.72	1.31	1.51	1.51	1.76
Duration of T, sec.	0.45	0.80	0.63	0.93	0.74	0.85
Heart rate, beats/minute	34	23	37	30	29	25

TABLE 2.—THE ELECTRICAL NATURE OF THE P AND T WAVES OF THE ELECTROGRAM OF THE TURTLE HEART IN SITU AND AFTER ISOLATION

Group A, control; Group B, long-term hypothermia; Group C, short-term hypothermia.

	Group A				Group B				Group C			
	P Wave		T Wave		P Wave		T Wave		P Wave		T Wave	
	In situ	Isolated	In situ	Isolated	In situ	Isolated	In situ	Isolated	In situ	Isolated	In situ	Isolated
Number +	2	1	0	0	8	1	0	1	7	0	0	1
Number −	2	3	0	0	2	10	0	1	1	9	0	0
Number −+	1	1	3	3	2	1	7	5	4	3	9	8
Number +−	0	2	4	4	0	0	5	5	0	0	3	3
Number indiscernible	2	0	0	0	0	0	0	0	0	0	0	0
Number changing sign upon isolation		3*		2		9		4		9		6

* This is only a minimum because 1 P wave was indiscernible because of flutter.

DISCUSSION

Kisch (1949) studied the electrogram of the univentricular heart (fish and bullfrog). He found that the electrogram recorded from the apex consisted of a high R and a small S component. In these studies (*in situ*) the S wave was almost always very deep (4 mv). Our studies on the electrogram of *Rana pipiens* show greater variability of the S wave than those recorded from the turtle. The T wave of the turtle electrogram was always diphasic. The electrograms recorded by Kisch (1949) were recorded using a modified form of Wilson's central terminal for an indifferent electrode. They show an upright T wave in the frog electrogram and a downward T wave in the fish electrogram. Hein and Reavis (1950) report a downward T wave for a V4 and D4 human electrogram. Burch and Winsor (1949) report that the human adults rarely, if ever, have a negative lead 4V; furthermore, the T wave is rarely notched or diphasic. The diphasic T wave

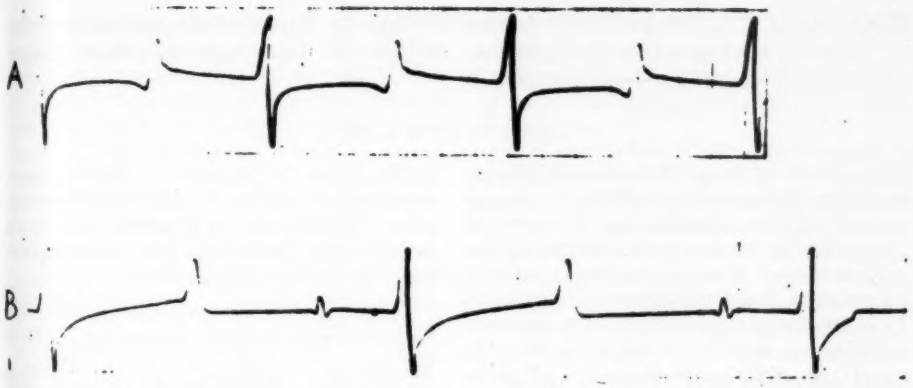

FIG. 1.—A, Typical electrogram with heart *in situ;* B, typical electrogram after isolation of the heart.

suggests that the repolarization pattern in the normal turtle is typical of systems with tissues of diverse repolarization rates (Churney, et al., 1948). This view is supported by the histological study of Robb (1953) which shows that the turtle heart contains a variety of muscular tissues.

Izquierdo (1930) maintains that the change in the heart rate of the isolated frog heart is due to the difference in composition of the ionic solution as compared with blood. These studies, while demonstrating a uniformity of response in three groups of turtles, does not offer information relative to this problem. What is of significance, however, is the fact that the decrease in heart rate accompanying isolation is attributable to components of the electrogram other than the QRS complex. If Izquierdo's view is correct, then it would be indicated that the ventricle conducting system is far less sensitive to changes in ionic composition than are the auricular conducting system and the factors responsible for repolarizarion—at least under the conditions of this experiment. The P wave was negative in 22 isolated hearts and negative in only 3 hearts *in situ* which suggests that after isolation, the direction of depolarization may be changed so that depolarization now proceeds from the epicardial surface to the endocardial surface instead of in the reverse direction. The R duration was not affected while the duration of the Q-T interval and T wave were greatly affected. The R wave amplitude, however, did decrease after isolation of the heart.

SUMMARY

A study of the heart rate and electrogram of the turtle heart *in situ* and after isolation, was made. Isolation of the heart resulted in a decrease in heart rate, change in direction of the P wave, diminution of the R amplitude, and increase in duration of the Q-T interval. The duration of the R wave was not affected. The T wave was almost always diphasic, *in situ* and after isolation. Little difference was noted when the electrograms of control animals were compared to the electrograms of turtles exposed to short-term and long-term hypothermia.

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ZOOLOGY.—*The new planktonic foraminiferal genus* Tinophodella, *and an emendation of* Globigerinita *Bronnimann.*

ALFRED R. LOEBLICH, JR., and HELEN TAPPAN, Smithsonian Institution.

(Received March 1, 1957)

In a study of Recent foraminiferal faunas, specimens were obtained which at first appeared to be referable to *Globigerinita naparimaensis* Bronnimann. Further examination showed that two distinct types were represented, and a restudy of Bronnimann's type specimens showed that both had been included by him in *G. naparimaensis*. As these types differ morphologically, the genus *Globigerinita* Bronnimann is here restricted to include only those species like the holotype of *G. naparimaensis*, the type species, and a new generic name is proposed for those which differ morphologically from that species as thus restricted. Various earlier writers have also separated specifically these two morphologic types in Recent deposits. Rhumbler (1909) described and illustrated specimens like the holotype of *G. naparimaensis* (= *Globigerinita*, s.s.) as the species *Globigerina lamellosa* Terquem. As noted by LeCalvez (1949, p. 38) and Parker (1954, p. 476), Terquem's species is quite unlike the present form. Parker recorded this latter type as *Globigerina* sp., stating that it was similar in many respects to *Globigerinita*, but probably "represents a new genus". Apparently she considered as typical *Globigerinita*, the paratypes there referred by Bronnimann, and did not consider the holotype of that species, which is morphologically more like her *Globigerina* sp., although specifically distinct.

Rhumbler (1909) recorded specimens similar to the paratypes of *G. naparimaensis* (not = *Globigerinita*, s.s.) as *Globigerina glutinata* Egger, although Egger's original description and figures appear to represent a distinct species of true *Globigerina*.

Phleger, Parker, and Pierson (1953, p. 16) followed Rhumbler's interpretation and recorded *Globigerinita glutinata* (Egger) as widely distributed in the North Atlantic, as did Parker (1954, p. 477), who recorded it as present in some abundance in the northeastern Gulf of Mexico.

The genus *Globigerinita* is therefore here emended and restricted, and the new generic name *Tinophodella* is proposed to include certain other forms that have been erroneously referred to *Globigerinita*.

Family ORBULINIDAE Schultze, 1854

Genus **Globigerinita** Bronnimann, 1951, emended

Globigerinita Bronnimann, Contr. Cushman Found. Foram. Res. **2** (pt. 1): 18 (part). 1951.

Type species.—*Globigerinita naparimaensis* Bronnimann, 1951. Fixed by original designation and monotypy.

Test free, trochospiral, early chambers spherical to ovate, final chamber modified and extending on the umbilical side across the umbilical region; sutures depressed, radial; wall calcareous, perforate, radial in structure, surface smooth or hispid; primary aperture interiomarginal and umbilical, in the final stage this primary aperture is covered by the modified final chamber which extends across the umbilical region and is replaced by one or more small arched supplementary apertures at the umbilical margin of the final chamber.

Remarks.—*Globigerinita* differs from *Globigerina* d'Orbigny in the presence of a modified final chamber which extends on the umbilical side to cover the earlier primary aperture and the umbilicus. *Tinophodella*, new genus, differs in having a distinct and separate supplementary plate over the umbilicus, extending somewhat along the sutures, with numerous accessory apertures along all margins.

In addition to the type species, *Globigerinita naparimaensis* Bronnimann, *Globigerina quinqueloba* Natland, and the new species here described as *G. parkerae* are referrable to this genus.

Range.—Miocene to Recent.

Globigerinita naparimaensis Bronnimann, restricted

Globigerinita naparimaensis Bronnimann (part), Contr. Cushman Found. Foram. Res. **2** (pt. 1): 18, text figs. 1, 2 (not figs. 3–14). 1951.

Not *Globigerinita naparimaensis* Bronnimann, Conato, Riv. Ital. Pal. Strat. **60** (1): 30, pl. 3, figs. 1–12. 1954.

Remarks.—Bronnimann (1951, p. 18) originally included in *Globigerinita naparimaensis*, a specimen with a modified final chamber and double aperture on the umbilical side (the holotype) and also other specimens (paratypes) which have a distinct umbilical-sutural "supplementary" chamber, with numerous accessory apertures around its periphery. The two forms were present in the same strata and were considered to be conspecific. As, in other horizons, the planktonic assemblage may include only one or the other type, they appear to be distinct and are here separated. The holotype of the present species (Bronnimann, 1951, text figs. 1, 2) has a modified final chamber which covers the *Globigerina*-like aperture of the previous chamber, and itself has two supplementary apertures at its umbilical margin. The true characters are well shown in Bronnimann's original figures of the holotype, and the species is here restricted to include only morphologically similar specimens.

The paratypes figured by Bronnimann (1951, text figs. 3–14) differ from the holotype in having a distinct supplementary plate over the umbilical and apertural region. This plate does not resemble the true chambers as does the umbilically expanded modified final chamber of true *Globigerinita*. These paratypes of *G. naparimaensis* are referrable to the new genus and species, *Tinophodella ambitacrena*.

Types and occurrence.—Holotype (Cushman Coll. 64182) from the Lengua formation, *Globorotalia menardii* zone, Miocene, Naparima area, Trinidad, B. W. I. The species as here restricted is known only from the Miocene of Trinidad.

Globigerinita parkerae Loeblich and Tappan, n. sp.
Figs. 1a–c

Globigerina lamellosa Terquem, Rhumbler (not Terquem, 1882), Ergeb. Plankton-Exped. Humboldt-Stift. **3:** pl. 30, figs. 1–6. 1909.
Globigerina sp. F. Parker, Bull. Mus. Comp. Zool. **111** (10): 476. 1954.

Test free, tiny, trochospiral, compressed, sides flattened, periphery rounded, peripheral outline lobulate; chambers ovate to spherical, increasing slowly in size, 5 to 7 in the final whorl, with modified final chamber extending far onto the umbilical side to completely cover the umbilical region; sutures distinct, depressed, radial; wall calcareous, finely perforate, surface finely spinose; primary aperture in the early stages interiomarginal and umbilical, but that of the modified final chamber is multiple, consisting of small arched supplementary openings around the extended umbilical margin of the final chamber.

Greatest diameter of holotype 0.21 mm, thickness 0.07 mm.

Remarks.—*Globigerina lamellosa* Terquem of Rhumbler (1909, pl. 30, figs. 1–6) is undoubtedly identical with the present species. However, Terquem's species was originally described from the Lutetian (middle Eocene) of the Paris Basin. The original illustration is poor and diagrammatic, and could represent any coiled form. It was described as having lamellar expansions from the later chambers which cover the apertural region. Le Calvez (1949, p. 38), stated that this species is not a *Globigerina*, and the type specimen of Terquem is in reality a *Discorbis*, analogous to *Rotalina coarctata* Terquem or *Rosalina propinqua* Terquem. She therefore considered (Le Calvez, 1949, p. 17) that *G. lamellosa* Terquem was a synonym of *Discorbis propinqua* (Terquem).

Parker (1954) recorded this species as *Globigerina* sp., although noting that it was similar to *Globigerinita*. She stated that it probably represented a new genus. However, it is similar to the holotype of *Globigerinita naparimaensis* Bronnimann having only a modified final chamber and lacking the secondary umbilical plate of the adult stage, such as is found in *Tinophodella ambitacrena*, new species.

Globigerinita parkerae, new species, differs from *G. naparimaensis* Bronnimann in being much smaller, with more chambers per whorl, and these are less closely appressed and show a more gradual increase in size.

The present species differs from *Globigerina quinqueloba* Natland in being much smaller, in having more chambers in the final whorl and a more gradual increase in chamber size, and more numerous supplementary apertures in the final chamber.

The specific name is in honor of Miss Frances Parker, Scripps Institution of Oceanography, La Jolla, Calif., in recognition of her work on Recent foraminiferal faunas.

Types and occurrence.—Holotype (U.S.N.M. P5897) from the Recent, eastern Gulf of Mexico, lat. 29°04′ N., long. 85°49′ W., depth 183 meters. Sample received from Frances Parker.

Tinophodella Loeblich and Tappan, n. gen.

Type species.—*Tinophodella ambitacrena* Loeblich and Tappan, n. sp.

Derivation.—*Teino*, Gr., stretch, extend, spread + *phos*, *phodos*, Gr., blister + *ella*, diminutive. Gender, feminine.

Test free, trochospiral; chambers spherical to ovate; sutures depressed, radial; wall calcareous, perforate, radial in structure, surface smooth, pitted or hispid; primary aperture interiomarginal, umbilical, in the final stage the aperture is completely covered by an irregular plate which covers the umbilicus and expands along the earlier sutures, with numerous accessory apertures along the margins of the umbilical plate, both at the junction of the plate with the sutures of earlier chambers, and along the contact with the primary chambers.

Remarks.—This genus includes forms which have in the past been variously referred to *Globigerina* d'Orbigny, *Globigerinatella* Cushman and Stainforth and *Globigerinita* Bronnimann. As here emended, *Globigerinita* is now restricted to include only forms with a modified final chamber with supplementary apertures and the present genus differs in having a distinct umbilical plate with numerous small accessory apertures opening beneath its margin.

Globigerinoita Bronnimann differs in having supplementary apertures on the spiral side which are also covered by small cover plates.

Range.—Miocene to Recent.

Tinophodella ambitacrena Loeblich and Tappan, n. sp.

Figs. 2a–3c

Globigerina glutinata Egger, Rhumbler (part, not Egger, 1893), Ergeb. Plankton-Exped. Humboldt-Stift. **3:** 148, pl. 29, figs. 15, 18–20, 22, pl. 34, fig. 1 (not pl. 29, figs. 14, 16, 17, 21, 23–26, and not pl. 33, fig. 20). 1909.

Globigerinatella aff. *insueta* Cushman and Stainforth, Bronnimann, Contr. Cushman Found. Foram. Res. **1:** (pts. 3–4): 82, pl. 14, fig. 11. 1950.

Globigerinita naparimaensis Bronnimann (part), Contr. Cushman Found. Foram. Res. **2** (pt. 1): 18, text figs. 3–14 (not text figs. 1–2). 1951; Conato, Riv. Ital. Paleon. Strat. **60** (1): 30, pl. 3, figs. 1–12. 1954.

Globigerinita glutinata (Egger), Phleger, Parker, and Pierson (part), Rept. Swedish Deep-Sea Exped. **7** (1): 16, pl. 2, fig. 15 (not figs. 12–14). 1953; Parker, Bull. Mus. Comp. Zool. **111** (10): 477. 1954.

Test free, inflated, low trochospiral, with broadly rounded periphery; chambers inflated, globular, increasing rapidly in size, early whorls with 4 to 5 chambers per whorl, rapidly reducing to 3 per whorl, which is most common in the adult; sutures distinct, depressed, radial; wall calcareous, finely perforate, surface finely spinose; primary aperture interiomarginal, umbilical, in the adult covered by a thin-walled umbilical plate which extends along the sutural depression over most of the umbilical side, and may even extend slightly onto the spiral side, outer margin of the umbilical plate with numerous accessory apertures which lie against the primary chambers and over the sutures as well, to open beneath the umbilical plate.

Greatest diameter of holotype 0.35 mm, thickness 0.25 mm.

Remarks.—The specific name is from the Latin *ambitus*, circumference + *crena*, notch, rounded projection. The name refers to the crenulated appearance of the border of the umbilical plate, caused by the accessory apertures.

Rhumbler (1909) referred this form to *Globigerina glutinata* Egger, but the latter species appears to be a true *Globigerina*, and shows no trace of a supplementary chamber on the umbilical side. Rhumbler also included specimens of *Globigerinoides* under Egger's species, but these differ in having supplementary apertures on the spiral side, as well as in lacking the umbilical cover plate.

Phleger, Parker, and Pierson (1953) followed Rhumbler's interpretation of Egger's species, but placed it in the genus *Globigerinita*. They also included specimens of a distinct species of *Globigerinoides* under this name.

Bronnimann (1950) figures a specimen of the present species as *Globigerinatella* aff. *insueta* Cushman and Stainforth, and the following year (1951) included it in the synonymy of *Globigerinita naparimaensis*. All figured paratypes of *G. naparimaensis* belong to the present species, as they differ in their apertural character from the holotype. Other writers have also recorded the present species as *G. naparimaensis* (i.e., Conato, 1954), but true *G. naparimaensis* is known only from the Miocene of Trinidad, having a modified final chamber, but no true cover plate.

The present species occurs in the Miocene of Trinidad, Pliocene of Italy, and Recent of the North and South Atlantic and the Gulf of Mexico.

Types and occurrence.—Holotype (U.S.N.M. P5898) and figured paratype (U.S.N.M. P5899) from the Recent, *Albatross* station D 2763, off the east coast of Brazil, lat. 24°17′00″ S., long.

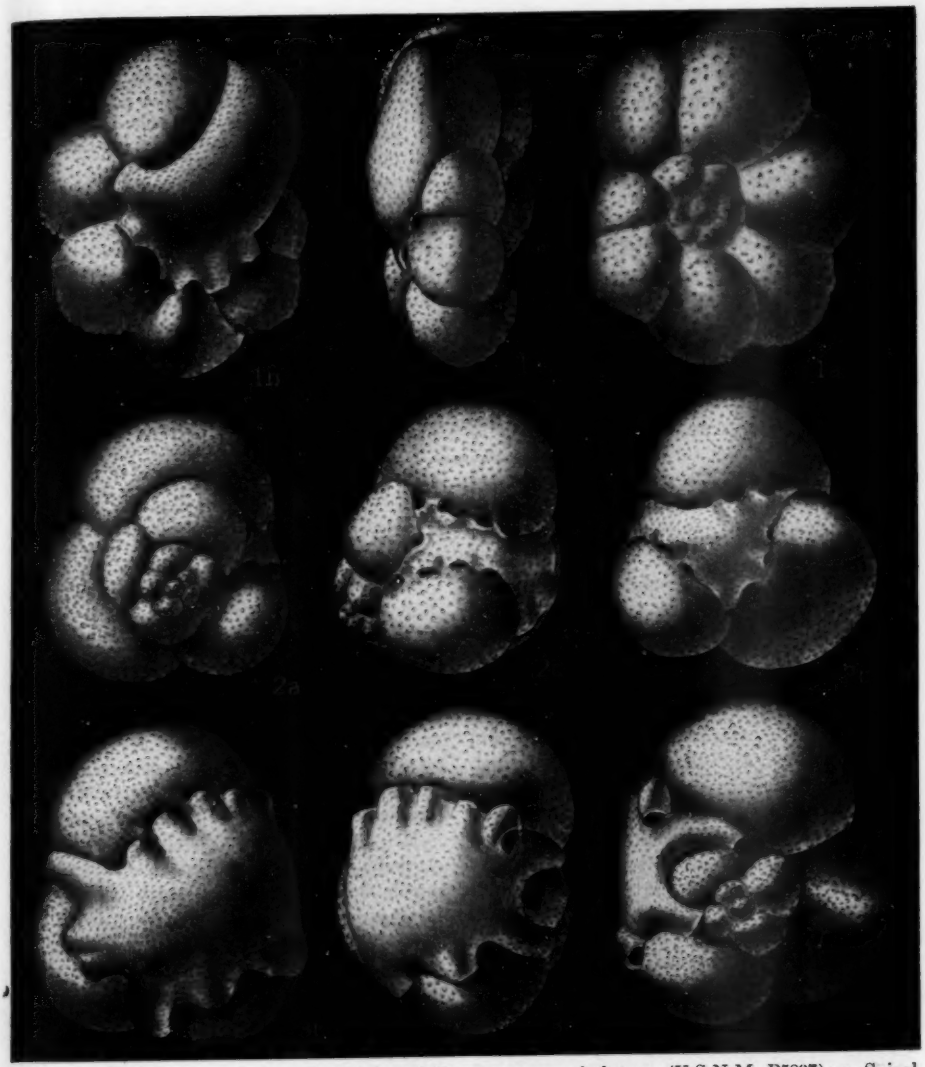

FIG. 1.—*Globigerinita parkerae* Loeblich and Tappan, n. sp., holotype (U.S.N.M. P5897): *a*, Spiral side, showing normal appearing final chamber; *b*, umbilical side, showing modification of the final chamber, and extension over the umbilical-apertural region, and the numerous supplementary apertures at its margin; *c*, edge view, showing compressed form. × 280.

FIGS. 2, 3.—*Tinophodella ambitacrena* Loeblich and Tappan, n. gen., n. sp.: *a*, Spiral side; *b*, umbilical side; *c*, edge. 2, Paratype (U.S.N.M. P5899), showing relatively small umbilical cover which is distinct from the true chambers, and occupies the umbilical-sutural area. 3, Holotype (U.S.N.M. P5898), showing extensive umbilical cover plate and distinctly crenulated margin, due to the numerous accessory apertures. × 145.

Illustrations are shaded camera-lucida drawings by Patricia Isham, scientific illustrator, Smithsonian Institution.

42°48′30″ W., depth 671 fathoms. Surface temperature 75°F., bottom temperature 37.9°F. Brown *Globigerina* ooze.

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WEIGHT OF METEORITE

The great shooting star that plunged to earth thousands of years ago and dug the famous Arizona Meteorite Crater weighed at least 12,000 tons (the size of an average house) and approached from a direction slightly south of west. Hitherto it has been estimated that the giant meteorite weighed between 10,000 and 10,000,000 tons, and that it crashed to earth from a point slightly west of north. These most recent measures of weight and direction are based on an on-the-spot study by scientists of the Smithsonian Astrophysical Observatory headed by Dr. John S. Rinehart, assistant director of the observatory.

Direction of the meteorite's flight was determined by sampling earth over an 80-square-mile area for tiny fragments of the meteorite. These particles of metals were found distributed over a symmetrical swath running nearly west to east (actually 15° north of east). Samples were taken every half mile in a square pattern, and sifted by screen and magnetic separator. Particles adhering to the magnet were all strongly magnetic and mainly in three categories: a meteoric iron particle, a meteoric iron-oxide bit, and a shiny particle probably volcanic.

From the area immediately surrounding the crater—which is 4,100 feet in diameter and about 600 feet deep—the scientists sampled earth that contained a concentration of meteorite particles. The weight of these particles, taking into consideration the area over which they were collected, constituted the basis for estimating the 12,000-ton weight of the meteorite.

Dr. Rinehart points out that a ballistics estimate previously made determined that the missile would have had to weigh 12,000 tons to have made a crater of the dimensions of the one in Arizona. His report on the survey states that there is no evidence to indicate any sizable portion of the meteorite lies under the floor of the crater. The meteor apparently exploded on impact, scattering into bits and chunks. The larger pieces remain now as particles, and the original smaller pieces have undoubtedly disintegrated through oxidization since the meteor fell thousands of years ago. The time is estimated variously at from 5000 to 50,000 years ago.

The true logic for this world is the calculus of probabilities, the only mathematics for practical men.—MAXWELL.

ENTOMOLOGY.—*Type specimens of mosquitoes in the United States National Museum, V: The Sabethini (Diptera, Culicidae).*[1]

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(Received February 12, 1957)

The introductory remarks in the first paper of this series, particularly those on early, possibly questionable holotypes, also apply to this one. Following our treatment of nominal taxa in each genus, we list those in the collection based on unique specimens or for which holotypes were clearly designated.

Genus **Limatus** Theobald

Limatus cacophrades Dyar and Knab, Smithsonian Misc. Coll. **52:** 266. 1909.

This species was based upon 12 specimens collected from a series by A. H. Jennings at Tabernilla, Canal Zone, Panama. Since only two specimens are labeled as types in the collection, it is impossible to tell which of the rest of the series are syntypic. We select as lectotype the male, bearing the labels "385.1/A. H. Jennings/Type No. 12130 U.S.N.M." The terminalia are not mounted, but the larval and pupal skin of this specimen are on a slide.

Limatus methysticus Dyar and Knab, Smithsonian Misc. Coll. **52:** 266, 1909.

The two male and two female syntypes are in the collection. We select as lectotype a male bearing the labels "Port Limon, C. R./Fredk Knab Collector/Type No. 12131 U.S.N.M./See Slide No. 368/*methysticus*." The terminalia are mounted on slide no. 368.

Limatus hoffmani Root, 1927. Holotype, unique.

Genus **Malaya** Leicester

Since the generic name *Malaya* Leicester (Cul. Malaya, p. 258, 1908) is earlier than *Grahamia* Theobald, May 1909, or *Harpagomyia* de Meijere, December 1909, and since it is not preoccupied by *Malaia* Heller, 1892, we adopt this name in place of the generally used *Harpagomyia*.

Harpagomyia caeruleovittata Ludlow, 1911. Holotype, unique.

Genus **Phoniomyia** Theobald

Wyeomyia (*Dodecamyia*) *incaudata* Root, *in* Dyar, Mosquitoes of the Americas: 54. 1928.

The original description is of the male, with no statement as to the number of specimens, although two collection dates are given. There is only one specimen taken by Root in the collection. This male, which we select as lectotype, is labeled "Rio, Brazil, April. 12, 1925 No. 66/Type No. 44163 U.S.N.M." The terminalia are mounted on a slide. The date of collection agrees with neither the February 15 nor May of the original description, but since Root labeled the slide as type, we think it should be accepted as such. It is possible that the larva collected on April 12 produced an adult on May 1.

Wyeomyia (*Dodecamyia*) *pilicauda* Root, *in* Dyar, Mosquitoes of the Americas: 55. 1928.

The female and male were described by Root and the larva by Dyar in the original publication. The collection contains one original specimen, a male, labeled "P. das Caixas, Brazil, May 29, 1925, No. 95.2/Type No. 44164 U.S.N.M." The slide, which was labeled as type by Root, contains the male terminalia and the larval and pupal skins. The date and locality do not agree with the original description, but we think it can be assumed that the original "Rio de Janeiro" refers to the state, and the date "June 7, 1925" the date of emergence of the adult from a larva collected on May 29. We select this single male as lectotype.

Genus **Sabethes** Robineau-Desvoidy

Sabethes bipartipes Dyar and Knab, Proc. Biol. Soc. Washington **19:** 136. 1906.

The two female syntypes are in the collection. We select as lectotype the better specimen. It

[1] Earlier papers of this series appeared in this JOURNAL **45:** 282–289. 1955; **46:** 213–228, 276–280. 1956; **47:** 42–59. 1957.

[2] Studies upon which this paper is based were conducted under an exchange of funds from the Office of Naval Research (Biological Science Division) to the Smithsonian Institution. The opinions or assertions contained here are the private ones of the writers and are not to be construed as official or reflecting the views of the Navy Department or the Naval Service at large.

bears the labels "St. Domingo W. I. Aug./Aug. Busck Collector/Type No. 9980 U.S.N.M./ *Sabethes nitidus* Theob."

Sabethes identicus Dyar and Knab, Journ. New York Ent. Soc. **15:** 207. 1907.

This species was described from four specimens from Tabernilla, Canal Zone, Panama, collected by August Busck. One female bears the labels "51.2/Tabernilla, Canal Zone, Panama/Collector August Busck/Type No. 10851 U.S.N.M./ *Sabethes identicus* D. & K. Type." Since this is the only one of a considerable number from Tabernilla that bears a type label, we consider it to be the holotype.

Sabethes tarsopus Dyar and Knab, Proc. U. S. Nat. Mus. **35:** 62. 1908.

This species was described from three specimens collected in Panama and Mexico. These three females are in the collection and we select as lectotype the one bearing the labels "Bocas d. Toro, 28 Sept., 03/U.S.D.A. No. 10413/P. Osterhout Collector/Type No. 11972 U.S.N.M./ *Sabethes longipes* Fabr./*Sabethes tarsopus* D. & K. Type."

Sabethoides undosus Coquillett, Proc. Ent. Soc. Washington **7:** 186. 1906.

This species was described from 10 specimens collected in Trinidad by Urich and Busck. All these are in the collections and the only one bearing a type label we consider to be the holotype. This female bears the labels, "Trinidad, W.I./F. W. Urich Collector/B 3.6/Type No. 8292 U.S.N.M./*Sabethoides undosus* Coq."

Holotypes, designated or unique:

Sabethoides chroiopus Dyar and Knab, 1913.
Sabethoides glaucodaemon Dyar and Shannon, 1925.
Sabethes goeldii Howard, Dyar and Knab, 1915.
Sabethes schausi Dyar and Knab, 1909.

Genus **Topomyia** Leicester

Holotypes, designated or unique:

Topomyia barbus Baisas, 1946.
Topomyia dejesusi Baisas and Feliciano, 1953.
Kingia gregoryi Ludlow, 1911.
Topomyia hernandoi Baisas and Feliciano, 1953.
Topomyia imitatus Baisas, 1946.

Genus **Trichoprosopon** Theobald

Lesticocampa dicellophora Howard, Dyar, and Knab, Mosquitoes of North and Central America and the West Indies **2:** figs. 43, 305. 1913; **3:** 166. 1915.

This name was first validated by publication of figures of the male terminalia and larva, followed by descriptions of the female, male, and larva in 1915. There are 15 specimens in the collection, each bearing the label "Type No. 12708 U.S.N.M." We select as lectotype a male bearing the additional labels "476.3/1763." This was reared from a larva collected at Miraflores, Panama, February 8, 1909, by A. H. Jennings. The terminalia are on slide no. 1763.

Phoniomyia homotina Dyar and Knab, Proc. Biol. Soc. Washington **19:** 141. 1906.

The five original specimens are in the collection. Only one bears a type label, and this we consider the holotype. This female bears the labels "Port Limon, C. R./Fredk Knab Collector/ Type No. 9993 U.S.N.M."

Lesticocampa lampropus Howard, Dyar, and Knab, Mosquitoes of North and Central America and the West Indies **2:** fig. 44, 1913. **3:** 167. 1915.

This name was first validated by the publication of a figure of the male terminalia in 1913. In 1915 the full descriptions of female and male were given. The lectotype selected by Stone (1944, p. 340) is in the collection.

Lesticocampa leucopus Dyar and Knab, Proc. Biol. Soc. Washington **19:** 137. 1906.

The five female syntypes are in the collection. We select as lectotype the one bearing the labels "Bluefields, Nicaragua/W. F. Thornton Collector/Type No. 10,003 U.S.N.M./*Lesticocampa leucopus* D. & K. Type."

Joblotia mogilasia Dyar and Knab, Journ. New York Ent. Soc. **15:** 206. 1907.

The lectotype female selected by Stone (1944, p. 338) is in the collection.

Lesticocampa moralesi Dyar and Knab, Ins. Insc. Mens. **7:** 3. 1919.

Both female syntypes are in poor condition. We select as lectotype one bearing the labels "S. Felipe, Dpto. Retalhuleu, Guat./Dr. Morales Coll./Type No. 21997 U.S.N.M."

Lesticocampa rapax Dyar and Knab, Proc. Biol. Soc. Washington **19:** 137. 1906.

The lectotype male selected by Stone (1944, p. 339) is in the collection.

Lesticocampa schedocyclia Dyar and Knab, Proc. U.S. Nat. Mus. **35:** 64. 1908.

The two female syntypes are in the collection, both bearing the labels "Bluefields, Nicaragua/ W. F. Thornton Collector/Type No. 11974 U.S.N.M." We select one as lectotype.

Trichoprosopon (*Joblotia*) *shropshirei* Ludlow, Psyche **26:** 168. 1919 [1920].

Four of the five female syntypes are in the collection, each labeled "Type No. 27803 U.S.N.M." We select as lectotype the one bearing the additional label, "*Trichoprosopon shropshirei* Ludl. Ancon, C. Z. July."

Joblotia trichorryes Dyar and Knab, Journ. New York Ent. Soc. **15:** 206. 1907.

The lectotype male selected by Stone (1944, p. 338) is in the collection. He erroneously stated this specimen to be a female.

Lesticocampa vonplesseni Dyar and Knab, Proc. Biol. Soc. Washington **19:** 137. 1906.

The four female syntypes are in the collection, labeled as having been collected by M. Grabham. These were actually collected by Baron von Plessen on the Upper Pastazza River and sent to Dyar by Grabham. One specimen is labeled "Pastazza R. Superior, Peru," but it is probable that these were collected in the Ecuadorian portion of the river. We select the best of the four as lectotype.

Trichoprosopon wilsoni Ludlow, Psyche **25:** 66. 1918.

As pointed out by Stone (1944, p. 335), there are no specimens in the collection bearing original data, although there are specimens labeled as type. For this reason it does not seem advisable to select a lectotype.

Holotypes, designated or unique:

Trichoprosopon (*Runchomyia*) *cerqueirai* Stone, 1944.
Lesticocampa culicivora Dyar and Knab, 1907.
Trichoprosopon (*T.*) *digitatum* var. *townsendi* Stone, 1944.
Lesticocampa trichopus Dyar, 1919.
Lesticocampa ulopus Dyar and Knab, 1906.

Genus **Tripteroides** Giles

Rachionotomyia monetifera Dyar, Ins. Insc. Mens. **8:** 176. 1920.

The female collected at Los Baños, P. I., selected as lectotype by Bohart and Farner (1944, p. 72) is in the collection.

Wyeomyia (*Dodecamyia*) *mus* Dyar, Ins. Insc. Mens. **8:** 176. 1920.

The two syntypes, a female and a male, labeled "Los Baños, P. I., 16-II, 1915" are in the collection. The male is in very poor condition, but since the terminalia are well preserved on a slide we select as lectotype this specimen, which bears the additional labels "1315/Type No. 23715."

Holotypes, designated or unique:

Tripteroides (*T.*) *apoensis* Baisas and Ubaldo-Pagayon, 1952.
Tripteroides (*T.*) *barraudi* Baisas and Ubaldo-Pagayon, 1952.
Tripteroides (*T.*) *belkini* Baisas and Ubaldo-Pagayon, 1952.
Tripteroides (*T.*) *binotata* Belkin, 1950.
Tripteroides (*T.*) *christophersi* Baisas and Ubaldo-Pagayon, 1952.
Tripteroides (*Mimeteomyia*) *coheni* Belkin, 1950.
Tripteroides (*T.*) *delpilari* Baisas and Ubaldo-Pagayon, 1952.
Tripteroides dyari Bohart and Farner, 1944.
Tripteroides (*T.*) *dyi* Baisas and Ubaldo-Pagayon, 1952.
Tripteroides (*T.*) *erlindae* Baisas and Ubaldo-Pagayon, 1952.
Tripteroides (*T.*) *powelli escodae* Baisas and Ubaldo-Pagayon, 1952.
Tripteroides floridensis Belkin, 1950.
Tripteroides folicola Belkin, 1950.
Tripteroides hoogstraali Baisas, 1947.
Tripteroides (*T.*) *indeterminata* Baisas and Ubaldo-Pagayon, 1952.
Tripteroides (*T.*) *intermediata* Baisas and Ubaldo-Pagayon, 1952.
Tripteroides (*T.*) *knighti* Baisas and Ubaldo-Pagayon, 1952.
Tripteroides (*T.*) *powelli laffooni* Baisas and Ubaldo-Pagayon, 1952.
Tripteroides (*T.*) *lipovskyi* Belkin, 1950.
Tripteroides (*Rachisoura*) *mabinii* Baisas and Ubaldo-Pagayon, 1952.
Tripteroides (*T.*) *malvari* Baisas and Ubaldo-Pagayon, 1952.
Tripteroides (*Rachisoura*) *mathesoni* Belkin, 1950.
Tripteroides (*T.*) *powelli mattinglyi* Baisas and Ubaldo-Pagayon, 1952.
Tripteroides melanesiensis Belkin, 1955.
Rachionotomyia microcala Dyar, 1929.

Uranotaenia powelli Ludlow, 1909.
Tripteroides (*T.*) *roxasi* Baisas and Ubaldo-Pagayon, 1952.
Tripteroides (*T.*) *rozeboomi* Baisas and Ubaldo-Pagayon, 1952.
Tripteroides (*T.*) *simulata* Baisas and Ubaldo-Pagayon, 1952.
Tripteroides (*Rachisoura*) *stonei* Belkin, 1950.
Tripteroides (*T.*) *sullivanae* Baisas and Ubaldo-Pagayon, 1952.
Tripteroides (*T.*) *toffaletii* Baisas and Ubaldo-Pagayon, 1952.
Tripteroides (*Rachisoura*) *torokinae* Belkin, 1950.
Tripteroides (*T.*) *uichancoi* Baisas and Ubaldo-Pagayon, 1952.
Tripteroides (*T.*) *werneri* Baisas and Ubaldo-Pagayon, 1952.

Genus **Wyeomyia** Theobald

Wyeomyia abascanta Dyar and Knab, Proc. U. S. Nat. Mus. **35:** 65. 1908.

The two syntypes, a male and a female, are in the collection. We select as lectotype the female, bearing the labels "Trinidad, W. I. Jun./Type No. 11983 U.S.N.M./*Wyeomyia abascanta* D. & K. Type." The male terminalia were apparently mounted, but the slide has not been found, and so we select the female, which is in much better condition.

Wyeomyia abebela Dyar and Knab, Proc. U. S. Nat. Mus. **35:** 67. 1908.

This species was described from six syntypes of both sexes, but only two specimens bear type labels and the others have not been found. One of these consists of one leg only. We select as lectotype the other, a male, no. 430.7 with terminalia and a portion of the pupal skin on slide no. 355. This was reared from a larva collected at Córdoba, Mexico, March 17, 1908, by Knab.

Wyeomyia abia Dyar and Knab, Proc. U. S. Nat. Mus. **35:** 67. 1908.

The two syntypes of this species are in the collection. The male lacks most of the abdomen but no slide mount of it has been found. The female bears the labels, "Dominica, W. I./F. E. Campbell Collector/4-2/Type No. 11988 U.S.N.M./*Wyeomyia proper* HGD 1922/*Wyeomyia abia* D. & K. Type". We select this female as lectotype.

Wyeomyia ablabes Dyar and Knab, Proc. U. S. Nat. Mus. **35:** 66. 1908.

The authors of this species described it from 18 specimens, "selected from a series." There are four numbered series (414, 415, 421, 430) agreeing with the original data and aggregating 25 specimens, but no one series reaches 18 in number. There are also 13 additional specimens from the type locality without rearing data. Two pins bear the labels, "Type No. 11986 U.S.N.M." and a third bears Dyar's hand written type label, but only one of these three specimens remains on the pin. It is impossible to determine which of the remaining specimens are the 15 other syntypes. We select as lectotype the only specimen left marked as type, a male, no. 421.103 with terminalia on slide no. 302.

Wyeomyia ablechra Dyar and Knab, Proc. U. S. Nat. Mus. **35:** 66. 1908.

Twelve of the 18 female syntypes of this species are in the collection, all bearing the labels, "Sonsonate, Salv./Fredk Knab Collector." One bears the labels, "Type No. 11895 U.S.N.M./*Wyeomyia ablechra* D. & K. Type" and we select this as lectotype.

Wyeomyia abrachys Dyar and Knab, Smithsonian Misc. Coll. **52:** 262. 1909.

The one female and two male syntypes are in the collection. We select as lectotype the male, bearing the labels, "119.3/A. H. Jennings Collector/Type No. 12133 U.S.N.M./See slide No. 436/*abrachys*." The terminalia are mounted on slide no. 436 and the larval skin on another slide.

Wyeomyia adelpha Dyar and Knab, Proc. Biol. Soc. Washington **19:** 140. 1906.

Ten of the 11 original specimens are in the collection, all bearing the labels, "Esparta, C. R./Fredk Knab Collector." No one of these females bears a type label, and it is possible that the specimen that had been labeled type is lost, but we select one of these ten specimens as the lectotype.

Wyeomyia andropus Dyar and Knab, Proc. U. S. Nat. Mus. **35:** 68. 1908.

The 26 syntypes of this species are in the collection, two bearing the label "Type No. 11989 U.S.N.M." and a third "*Wyeomyia andropus* D. & K. Type." We select as lectotype the male (No. 133.2) with terminalia unmounted, bearing the Museum type label. This was reared from a larva collected in a bromeliad at Porto Bello,

Fort San Felipe, January 4, 1909, by A. H. Jennings.

Wyeomyia aporonoma Dyar and Knab, Journ. New York Ent. Soc. **14:** 230. 1906.

This species was described from larvae only, collected in Salvador, Mexico, and Costa Rica by Knab. The collection contains three specimens bearing red type labels and six others probably of the type series. One of these specimens with a red type label and one without each bear Dyar's hand-written label "*Wyeomyia aporonoma* D. & K. Type." Only one larval skin was found that could be associated with the four specimens marked as types. We select this (no. 330zd) as lectotype and have mounted it with the associated pupal skin on a slide. The adult male from this pupa was reared from a larva collected at Sonsonate, El Salvador, August 30, 1905. It bears the labels "No. 330zd see F. Knab's Entom. notes/Sonsonate Salvador/Type No. 9983 U.S.N.M./*Dendromyia quasiluteoventralis* Theob.," the latter in Coquillett's hand.

Wyeomyia autocratica Dyar and Knab, Journ. New York Ent. Soc. **14:** 230. 1906.

This species was described from the larva of a single specimen and the larval skin is apparently lost. There is a male in the collection labeled "Trinidad W. I./F. W. Urich Collector/B 12-8/ Type No. 9986 U.S.N.M./See Slide No. 361/ *Wyeomyia autocratica* D. & K. Type." The terminalia are on one slide, the pupal skin on the other. This series can be considered holotypic although the portion originally described is lost.

Wyeomyia bahama Dyar and Knab, Proc. Biol. Soc. Washington **19:** 138. 1906.

Fifteen of the original 16 specimens are in the collection, all labeled, "Tarpon Bay, Bahamas, 7-7-03/T. H. Coffin Coll. No. 21." One only, a female, bears the label, "Type No. 9990 U.S.N.M." and we consider this the holotype.

Dendromyia (*Eunicemyia*) *bicornis* Root, *in* Dyar, Mosquitoes of the Americas: 50. 1928.

There is no statement concerning the type material of this species in the original description, but the male and larva were described and they were from Venezuela. There is one specimen only labeled as type and this male bears the labels, "Ocumare Ven., July 6, 1927. No. 108/108.1/ Type No. 44162 U.S.N.M." The terminalia are mounted on a slide, but no larval or pupal skins have been found. We consider this male the holotype.

Wyeomyia bromeliarum Dyar and Knab, Proc. Biol. Soc. Washington **19:** 138. 1906.

This was described from larvae that the authors had previously determined and figured as *W. assulepta* Theob. The collection contains a larval and a pupal skin in poor condition mounted on a slide labeled, "*Wyeomyia bromeliarum* D. & K. Type, Trinidad W. I., F. W. Urich Collector." All that is left of the adult reared from this larva are two legs on a point. We select the larval skin as lectotype, with which are associated the pupal skin and the small portion of the adult.

Wyeomyia cacodela Dyar and Knab, Smithsonian Misc. Coll. **52:** 265. 1909.

The two male and one female syntypes of this species are in the collection. We select as lectotype the male bearing the labels, "195/A. H. Jennings Collector/Type No. 12183 U.S.N.M./*Wyeomyia cacodela* D. & K. Type." This was reared from a larva collected at Gorgona, Canal Zone, in flower cups of Heliconia, February 7, 1908. The terminalia have not been mounted.

Wyeomyia (*W.*) *camptocomma* Dyar, Ins. Insc. Mens. **12:** 120. 1924.

This species was described from five males and ten females from Barranquilla, Colombia. These are in the collection and we select as lectotype the male bearing the labels, "1903/Barranquilla, Colomb./L. H. Dunn Coll. 1923/Type No. ——— U.S.N.M." The terminalia are mounted on slide no. 1903.

Sabethes canfieldi Dyar and Knab, Jour. New York Ent. Soc. **15:** 207. 1907.

Of the 23 original specimens from Lion Hill, Canal Zone, Panama, 18 have been found in the collection, all females. Only one bears a type label and this we consider the holotype.

Wyeomyia chalcocephala Dyar and Knab, Proc. Biol. Soc. Washington **19:** 140. 1906.

Only three of the seven original specimens have been found in the collection. One only, a male, bears a type label, and this we consider the holotype. The labels are, "Cacao Trece Aguas/

Alta V. Paz, Guatemala/Schwarz & Barber Coll/2/See Slide No. 352/Type No. 10,002 U.S.N.M." The terminalia are mounted on slide No. 352.

Wyeomyia chresta Dyar and Knab, Smithsonian Misc. Coll. **52:** 263. 1909.

The two syntypes, female and male, of this species are in the collection. We select as lectotype the male, bearing the labels, "Tabernilla, Canal Zone, Panama/216.3/Collected by August Busck/Type No. 12135 U.S.N.M./See slide No. 439/*chresta*." The terminalia are on slide no. 439 and the larval head capsule on another slide.

Wyeomyia circumcincta Dyar and Knab, Jour. New York Ent. Soc. **15:** 210. 1907.

The two syntype males of this species are in the collection, each bearing the labels, "191/Tabernilla, Canal Zone, Panama/Collected by August Busck/Type No. 10857 U.S.N.M." We select as lectotype the one also bearing the label "*Wyeomyia circumcincta* D. & K. Type."

Wyeomyia clasoleuca Dyar and Knab, Proc. U. S. Nat. Mus. **35:** 68. 1908.

The two female syntypes of this species are in the collection, both bearing the labels, "Caldera Isl., Porto Bello Bay/A. H. Jennings Collector/Type No. 11990 U.S.N.M." We select as lectotype the one bearing the determination label.

Wyeomyia codiocampa Dyar and Knab, Jour. New York Ent. Soc. **15:** 209. 1907.

Nine of the 11 original specimens are in the collection. One of each sex bears the label, "Type No. 10853 U.S.N.M." We select as lectotype the male, bearing in addition the labels, "461/Tabernilla, Canal Zone, Panama/Collected by August Busck/See slide No. 362." The slide bears the terminalia.

Wyeomyia coenonus Howard, Dyar, and Knab, Mosquitoes of North and Central America and the West Indies **2:** pl. 6, fig. 38. 1913; **3:** 153. 1915.

The first appearance of this name is in association with a figure of the male terminalia, followed by the written description of the female and male in 1915. The data for the species in this latter publication are, "Tabernilla, Canal Zone, April 14, 1909 and Upper Pequini River, March 27, 1909", both collected by A. H. Jennings. The collection contains two females and one male, each bearing Jennings' collection number 552 and the label, "Type No. 12705 U.S.N.M." We select the male as lectotype. The number is 552.3, the terminalia are on slide no. 523, labeled as type. No larval skin has been found. The specimen was reared from *Calathea* at Tabernilla, April 14, 1909.

Dendromyia (*Melanolepis*) *complosa* Dyar, Mosquitoes of the Americas: 74. 1928.

The female, male, and larva of this species were described from Panama and Venezuela. There are three females and one male from San Juan de Pequini, Panama, collected by D. P. Curry, none labeled as type, but presumably all syntypes. We select as lectotype the male, with terminalia mounted on slide no. 2285.

Wyeomyia conchita Dyar and Knab, Smithsonian Misc. Coll. **52:** 264. 1909.

This species was described from 14 specimens collected at San Antonio de los Baños, Cuba, by J. H. Pazos. There are 20 specimens bearing Pazos numbers but only one, a female, bears the type label. Since it is impossible to determine which are the syntypes in this series, we select as lectotype the female (no. 397) which bears the type label.

Wyeomyia drapetes Dyar and Knab, Smithsonian Misc. Coll. **52:** 264. 1909.

The one female and two male syntypes of this species are in the collection. We select as lectotype the male bearing the labels, "Trinidad, W. I./F. W. Urich Collector/Type No. 12181 U.S.N.M./See Slide No. 366/*drapetes*." The terminalia are mounted on slide no. 366.

Wyeomyia dymodora Dyar and Knab, Proc. U. S. Nat. Mus. **35:** 69. 1908.

Dyar and Knab (1909, p. 266) fixed the lectotype of this species by describing one of the two syntypes as a new species (*hapla*). This lectotype, with abdomen missing, is labeled, "157/A. H. Jennings Collector/Type No. 11991 U.S.N.M./*Wyeomyia dymodora* D. & K. Type." It was reared from a larva collected at Fort San Felipe, Porto Bello, January 21, 1908.

Wyeomyia eloisa Howard, Dyar, and Knab, Mosquitoes of North and Central America and the West Indies **2:** pl, 6, fig. 36. 1913; **3:** 121. 1915.

This name first appeared in association with a figure of the male terminalia, followed by the written descriptions of the female, male, and larva two years later. Three Panama localities are given in the later description. There are 50 specimens bearing the data given in the written description. Only one of these is labeled as type, but this is a female, and since the name first appeared in connection with a figure of the male we select as lectotype a male bearing the labels, "476/See Slide No. 505/Miraflores, C. Z., Pan./ Feb. 8. 09/A. H. Jennings Coll./*Wyeomyia eloisa* HDK." The terminalia are mounted on slide no. 505.

Wyeomyia fauna Dyar and Shannon, Ins. Insc. Mens. **7:** 12. 1919.

The two male and one female syntypes of this species all bear the labels, "Bas Obispo, C. Z., Pan. Aug., 1913/J. Zetek Coll./Type No. 21999 U.S.N.M." We select as lectotype the male bearing the additional labels, "1114/*Wyeomyia fauna* D. & K. Type." The terminalia are mounted on slide no. 1114.

Dendromyia (*Decamyia*) *felicia* Dyar and Nuñez Tovar, Notas Sobre Nuevos Dipteros Hematofagos de Venezuela, Maracay: 3. 1927.

This species was described from an unstated number of both sexes from four localities in Venezuela. There are a large number of specimens in the collection bearing data agreeing with those originally given, but only two males and a female are marked as types. All are labeled, "Tio Julian VII.8.1927/M. Nuñez Tovar Coll./Type No. ——— U.S.N.M." We select as lectotype the male bearing the additional label "elephant's ear."

Wyeomyia galoa Dyar and Knab, Proc. Biol. Soc. Washington **19:** 140. 1906.

Two of the three original specimens are in the collection. Only one of these bears a type label and this we consider the holotype. This female is labeled, "Cacao Trece Aguas/Alta V. Paz, Guatemala/Schwarz & Barber Coll./3 on Heliconica bracts/ Type No. 10,001 U.S.N.M."

Wyeomyia (*W.*) *gaudians* Dyar and Nuñez Tovar, Notas Sobre Nuevos Dipteros Hematofagos de Venezuela, Maracay: 5. 1927.

This species was described from four females and one male collected at Mariara, Carabobo, Venezuela, July 1927. There are no specimens in the collection labeled as types although there are many from the type locality collected in July. Many in the collection bear small red labels, but some of these were collected later than July. There are three females with small blue labels that bear original data, and a male mounted on a slide. We select as lectotype this male, bearing the label in Dyar's hand, "*Wyeomyia gaudians* D. & NT. Bromelias. Carabobo Ven. July 14, 1927. M. Nuñez Tovar." A small red label is also glued to this slide.

Wyeomyia glaucocephala Dyar and Knab, Proc. Biol. Soc. Washington **19:** 140. 1906.

There are a number of specimens in the collection bearing original data and it is impossible to determine which are from the type series of *W. ochrura* and which belong to *glaucocephala*. One female, with head missing bears the original type number of *glaucocephala* and this we consider the holotype. The labels are, "113/St. Domingo. W. I. Aug./Aug. Busck Collector/Type No. 9999 U.S.N.M."

Wyeomyia guatemala Dyar and Knab, Proc. Biol. Soc. Washington **19:** 139. 1906.

This species was described from two specimens although there are three in the collection bearing the original data. One only, a female, bears the type label (No. 9994) and this we consider the holotype. It was collected by Barber and Schwarz at Cacao Trece Aguas, Alta V. Paz, Guatemala, April 17.

Wyeomyia hemisagnosta Dyar and Knab, Jour. New York Ent. Soc. **14:** 230. 1906.

This was described from larvae collected at Sonsonate, Salvador and Port Limon, Costa Rica. The only original specimen found in the collection is a larval skin labeled "*Miamyia hemisagnosta* (D. & K.) Type 9984. Sonsonate, Salvador, Aug. 30, 1905 Knab 330pi." We select this slide-mounted skin as lectotype.

Wyeomyia (*W.*) *incana* Dyar, Ins. Insc. Mens. **10:** 189. 1922.

This species was described from, "Types, male and female, No. 25759 U. S. Nat. Mus.; Margarita, Canal Zone, Panama, August 12, 1922 (J.B. Shropshire)." There is one specimen of each sex so labeled in the collection. We select the male

as lectotype, with terminalia mounted on slide no. 1711.

Wyeomyia labesba Howard, Dyar, and Knab, Mosquitoes of North and Central America and the West Indies **2:** pl. 89, fig. 282. 1913; **3:** 106. 1915.

This name first appeared in association with a figure of the larval head and last two abdominal segments. The written description of the female and larva appeared in the next volume, with the data, Ancon, Canal Zone, December 24, 1908, and Tabernilla, Canal Zone, February 4, 1909. These are numbers 463 and 471 respectively of Jenning's notes and the collection contains three females bearing those numbers and labeled as types. There are also two larval skins but only one of these (no. 471.1) is associated with an adult "type." We select this larval skin as lectotype, the female reared from it also being lectotypic.

Wyeomyia macrotus Dyar and Knab, Jour. New York Ent. Soc. **15:** 212. 1907.

Two of the three syntypes are in the collection, each bearing the label, "Type No. 10862 U.S.N.M." We select as lectotype the female, also bearing the labels, "104.1/Collected by August Busck/Panama/*Wyeomyia macrotus* D. & K. Type." The remaining fragments of the larval and pupal skins of this specimen have been mounted on a slide. The larva was collected in a bromeliad on the Boqueran River, May 23, 1907.

Wyeomyia mataea Dyar and Knab, Proc. U. S. Nat. Mus. **35:** 70. 1908.

The two female syntypes of this species are in the collection. We select as lectotype the one labeled, "Sonsonate, Salvador/Fredk Knab Collector/Type No. 11994 U.S.N.M./*Wyeomyia matea* [sic] D. & K. Type."

Wyeomyia megalodora Dyar and Knab, Proc. U. S. Nat. Mus. **35:** 69. 1908.

This was described from two specimens, but there are four in the collection bearing identical data and only one labeled as type, so it is impossible to fix the second syntype. We select as lectotype the female labeled, "Sonsonate, Salvador/Fredk Knab Collector/Type No. 11993 U.S.N.M./*Wyeomyia megalodora* D. & K. Type."

Dendromyia (*Calladimyia*) *melanoides* Root, *in* Dyar, Mosquitoes of the Americas: 79. 1928.

The male, female, and larva of this species was described from two localities in Brazil. There are three males and two females in the collection labeled, "Magé, Brazil, May 26, 1925," one of them bearing the label, "Type No. 44165 U.S.N.M." The Rio de Janeiro specimens have not been found. We select as lectotype the male numbered 90-2 with the terminalia and pupal skin mounted on a slide.

Wyeomyia minor Dyar and Knab, Proc. Biol. Soc. Washington **19:** 138. 1906.

Four of the original seven specimens have been found in the collection. One only, a female, bears the type label (No. 9992) and this we consider the holotype. It was collected by August Busck at Baracoa, Cuba, September 1901.

Wyeomyia modalma Dyar, Ins. Insc. Mens. **10:** 97. 1922.

This species was described from five females. These are in the collection with type labels, there being four from Paja, not three as originally stated. We select as lectotype the one bearing the labels, "Gatun, C. Z. Pan./Dec. 10/J. B. Shropshire Coll. 1921/V-15/Type No. 25256 U.S.N.M./*Wyeomyia modalma* Dyar Type."

Wyeomyia mystes Dyar, Ins. Insc. Mens. **12:** 92. 1924.

The two pinned syntypes of this species are in the collection. We select as lectotype the male, bearing the labels, "Type No. ——— U.S.N.M./ Rio de Janeiro, Braz. Aug. 1922. F. L. Soper/ Slide 36.VII.28b." The terminalia are mounted on the slide.

Wyeomyia ochrura Dyar and Knab, Jour. New York Ent. Soc. **14:** 229. 1906.

This species was described in the larval stage only, from specimens collected in San Domingo by Busck, Trinidad by Urich, and Dominica by Campbell. Two specimens only bear type labels. These, a male and a female bear the labels, "St. Domingo, W. I. Aug./Aug. Busck Collector/Type No. 9987 U.S.N.M." We select as lectotype the larval skin No. 113.1 on the same slide with its pupal skin and with the larval and pupal skin of the other "type" (no. 113.2). The adult from this

lectotype larva is fragmentary but the terminalia are mounted on slide no. 365. The larval and pupal skins, pinned male and mounted terminalia are all lectotypic.

Wyeomyia onidus Dyar and Knab, Smithsonian Misc. Coll. **52:** 261. 1909.

The two female and one male syntypes of this species are in the collection. We select as lectotype the male, bearing the labels, "238.6/Type No. 12054 U.S.N.M./See Slide No. 356/*onidus*." The larvae from which the syntypes were reared were collected in the flower cups of Heliconia at Tabernilla, Canal Zone, March 12, 1908, by A. H. Jennings. The larval skin is mounted on another slide.

Wyeomyia pandora Dyar and Knab, Smithsonian Misc. Coll. **52:** 261. 1909.

The three female and one male syntypes of this species are in the collection and we select as lectotype the male, bearing the labels, "37/A. H. Jennings Collector/Type No. 12132 U.S.N.M./ See Slide No. 441/*pandora*." The larva from which this was reared was collected at Corozal, Panama, November 29, 1907. The terminalia are mounted on slide no. 441.

Wyeomyia pantoia Dyar and Knab, Smithsonian Misc. Coll. **52:** 262. 1909.

The four female and two male syntypes of this species are in the collection. We select as lectotype the male bearing the labels, "238/Type No. 12055 U.S.N.M./See Slide No. 442/*pantoia*." This was reared from a larva collected in flower cups of Heliconia at Tabernilla, Canal Zone, March 12, 1908 by A. H. Jennings. The terminalia are on slide no. 442.

Phoniomyia philophone Dyar and Knab, Jour. New York Ent. Soc. **15:** 209. 1907.

Fifteen of the original 20 specimens of this species have been found in the collection, one female only bearing a type label, and this we consider the holotype.

Wyeomyia prolepidis Dyar and Knab, Ins. Insc. Mens. **7:** 1. 1919.

The five female syntypes of this species are in the collection. We select as lectotype the one bearing the labels, "Culebra, C. Z., Pan./L. H. Dunn C-97/Type No. 21779 U.S.N.M./*Wyeomyia prolepidis* D. & K. Type."

Dinomyia proviolans Dyar, Ins. Insc. Mens. **7:** 117. 1919.

This was described from three males from two collections in Panama. These are in the collection, and we select as lectotype the one labeled, "Porto Bello, Pan. March 11, August Busck/1139/Type No. 22006 U.S.N.M./*Dinomyia proviolans* Dyar Type." The terminalia are on slide no. 1139.

Wyeomyia pseudopecten Dyar and Knab, Proc. Biol. Soc. Washington **19:** 139, 1906.

This species was described from eight specimens collected in Trinidad by August Busck and F. W. Urich. There are twelve specimens that bear proper data in the collection, but only one bears a type label, and this we consider the holotype. This male, with terminalia intact, bears the labels, "31/Trinidad, W. I. Jun./Aug. Busck Collector/Type No. 9997 U.S.N.M."

Phoniomyia scotinomus Dyar and Knab, Jour. New York Ent. Soc. **15:** 209. 1907.

Two of the original three specimens are in the collection, each bearing the label, "Type No. 10855 U.S.N.M." We select as lectotype the male, bearing additional labels, "103.1/Panama/collected by August Busck/See Slide No. 438/ *Phoniomyia scotinomus* D. & K. Type." The type locality is the Boqueron River; the terminalia are on slide no. 438, and the pupal skin and head of larval skin are on another slide.

Aedes smithii Coquillett, Can. Ent. **23:** 260. 1901.

Four of the five original specimens are in the collection. Only one bears a type label and this male we consider the holotype. It bears the labels, "Bred from larvae found Mch. and Apr. in leaves of pitcher plant at Lahaway, Ocean Co., N. J. First pupa obtained Apr. 14, first adult ten days later J. B. Smith/Type No. 5799 U.S.N.M./ *Aedes smithii* Coquillett."

Wyeomyia sororcula Dyar and Knab, Proc. Biol. Soc. Washington **19:** 139. 1906.

The 53 original specimens from St. Domingo, are in the collection. Only one is labeled as type, and we consider this to be the holotype. This female bears the labels, "S. Frncsco Mts., S. Domingo. W. I. September 05/Aug. Busck Collector/Type No. 9996 U.S.N.M."

Wyeomyia symmachus Dyar and Knab, Smithsonian Misc. Coll. **52:** 262. 1909.

The two syntype females of this species are in the collection, bearing the labels, "326/Type No. 12056 U.S.N.M." We select as lectotype the one labeled by Dyar, "*Wyeomyia symmachus* D. & K. Type." The larvae from which these specimens were reared were collected in bamboo traps at Tabernilla, Canal Zone, May 23, 1908, by A. H. Jennings.

Wyeomyia telestica Dyar and Knab, Jour. New York Ent. Soc. **14:** 230. 1906.

This species was originally described from the larva only. The collection contains an adult male bearing the labels, "Trinidad, W. I./F. W. Urich Collector/B 12-3/Type No. 9985 U.S.N.M./See Slide No. 360/*Wyeomyia telestica* D. & K. Type." Associated with this is a pupal skin but the larval skin is apparently lost. The type catalogue states, "1. Type of adult. Described from larva." We may assume that this adult was reared from the type larva, possibly the only larva before the authors, and it may be justifiably considered as holotypic.

Wyeomyia vanduzeei Dyar and Knab, Proc. Biol. Soc. Washington **19:** 138. 1906.

The 12 syntypes of this species are in the collection. We select as lectotype the male specimen labeled, "356.5/See Slide No. 349/Type No. 9988 U.S.N.M." This was reared from bromeliads at Estero, Florida.

Wyeomyia violescens Dyar and Knab, Proc. Biol. Soc. Washington **19:** 138. 1906.

Seven of the eight original specimens from Cayamas, Cuba, are in the collection. One only, a female, bears the type label (No. 9991) and this we consider the holotype. It was collected in a home, June 8, by E. A. Schwarz.

Holotypes, designated or unique:

Wyeomyia agnostipes Dyar and Knab, 1907.
Wyeomyia argyrtes Dyar and Knab, 1909.
Wyeomyia antoinetta Dyar and Knab, 1909.
Wyeomyia aphobema Dyar, 1918.
Wyeomyia argyrura Dyar and Knab, 1908.
Wyeomyia baria Dyar and Knab, 1908.
Wyeomyia cara Dyar and Knab, 1909.
Wyeomyia caracula Dyar and Nuñez-Tovar, 1927.
Wyeomyia celaenocephala Dyar and Knab, 1906.
Wyeomyia (*W.*) *charmion* Dyar, 1928.
Phoniomyia chrysomus Dyar and Knab, 1907.
Wyeomyia (*Menolepis*) *culebrae* Dyar, 1923.
Wyeomyia espartana Dyar and Knab, 1906.
Wyeomyia euethes Dyar and Knab, 1909.
Dendromyia (*Melanolepis*) *favor* Dyar and Nuñez-Tovar, 1928.
Wyeomyia (*Techniciomyia*) *florestan* Dyar, 1925.
Wyeomyia fratercula Dyar and Knab, 1906.
Wyeomyia (*W.*) *gausapata* Dyar and Nuñez Tovar, 1927.
Wyeomyia gynaecopus Dyar and Knab, 1908.
Wyeomyia hapla Dyar and Knab, 1909.
Wyeomyia haynei Dodge, 1947.
Prosopolepis hemisiris Dyar and Shannon, 1925.
Phoniomyia hirsuta Hill and Hill, 1946.
Wyeomyia homothe Dyar and Knab, 1907.
Wyeomyia hosautus Dyar and Knab, 1907.
Wyeomyia intonca Dyar and Knab, 1909.
Prosopolepis jocosa Dyar and Knab, 1908.
Wyeomyia leucopisthepus Dyar and Knab, 1907.
Wyeomyia melanocephala Dyar and Knab, 1906.
Wyeomyia melanopus Dyar, 1919.
Sabethinus moerbista Dyar and Knab, 1919.
Miamyia (*Shropshirea*) *pampithes* Dyar and Nuñez Tovar, 1928.
Wyeomyia panamana Dyar and Knab, 1907.
Miamyia petrocchiae Shannon and Del Ponte, 1928.
Wyeomyia phroso Howard, Dyar, and Knab, 1915.
Wyeomyia rolonca Dyar and Knab, 1909.
Wyeomyia roloncetta Dyar, 1919.
Sabethoides serratoria Dyar and Nuñez Tovar, 1927.
Phoniomyia simmsi Dyar and Knab, 1908.
Wyeomyia (*Shropshirea*) *ypsipola* Dyar, 1922.

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Entia non sunt multiplicanda praeter necessitatem.—WILLIAM OF OCCAM, 14th century

HERPETOLOGY.—*Contributions to the herpetology of Maryland and Delmarva, 15: The herpetofauna of Somerset County, Md.* CLYDE F. REED, Baltimore, Md. (Communicated by Doris M. Cochran.)

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Somerset County, Md., lies on the Delmarva Peninsula, bounded on the east (in part) and south by the Pocomoke Swamp and River, on the west by the Chesapeake Bay, and on the north by Wicomico County. A large portion of the county, especially the western, is marshy. The more inland portions toward the Pocomoke River are swampy. Between these two wet areas is the dry sandy portion. Therefore, the habitats, although they are all coastal soils, are either predominantly wet or predominantly dry.

Both Conant's *Checklist of the amphibians and reptiles of the Del-Mar-Va Peninsula* and McCauley's *Reptiles of Maryland and the District of Columbia*, both published in 1945, give very few records for any species of amphibians or reptiles from Somerset County. Along with Carroll and Caroline Counties in Maryland, this is one of the most poorly collected-in counties in the State. It is difficult to say whether their representation is due to inadequate collecting or species paucity. The counties to the north and east of Somerset, namely Wicomico and Worcester, are very well represented in species of herpetofauna. From the author's collecting in this county, it would appear that inadequate collections have been made. The author has been collecting in this county since 1938, mainly in the area about Waterloo Farm, at the Headwaters of Monie Creek, on the property of Philip Wolle of Princess Anne.

The published records for the amphibians and reptiles of Somerset County are quite meager. McCauley (l.c., 1945) lists five reptiles from the county: *Heterodon p. platyrhinos, Coluber c. constrictor, Lampropeltis g. getulus, Natrix s. sipedon* and *Malaclemys centrata concentrica*. Conant (l.c., 1945) lists five species of amphibians and reptiles from this county: *Pseudacris nigrita triseriata, Hyla c. crucifer, Rana clamitans, Rana pipiens* and *Coluber c. constrictor*.

Collections by the author and Philip Wolle indicate that there are at least 25 reptiles in the county. The records given herein may be considered as new to the county for all those species not mentioned above and additional records for all other species.

1. *Scaphiopus holbrooki holbrooki* (Harlan). North of Pocomoke City, July 9, 1956, *Reed* 1126.

2. *Bufo woodhousei fowleri* Hinckley. North of Pocomoke City, July 9, 1956, *Reed* 1127–1128.

3. *Hyla versicolor versicolor* LeConte. Northeast of Pocomoke City, July 9, 1956, *Reed* 1165–1166.

4. *Hyla crucifer crucifer* Wied. Conant, 1945.

5. *Pseudacris nigrita triseriata* (Weid). Conant, 1945.

6. *Rana clamitans* Latreille. 5 miles Southeast of Princess Anne, July 12, 1953, *Reed* 285; Conant, 1945.

7. *Rana catesbeiana* Shaw. Waterloo Farm, *Philip Wolle*; just north of Pocomoke City, July 9, 1956, *Reed*.

8. *Rana pipiens* Schreber. Swamp near Monie Bay, July 25, 1954, *Reed* 951.

9. *Ambystoma tigrinum tigrinum* (Green) 4 miles west of Princess Anne, *Philip Wolle*.

10. *Plethodon cinereus cinereus* (Green). Woods near Monie Creek, summer, 1938, *Reed*.

11. *Sceloporus undulatus hyacinthinus* (Green): Fence swift. Waterloo Farm, headwaters of Monie Creek, *Philip Wolle*; September 1941, *Reed*.

12. *Heterodon platyrhinos platyrhinos* Latreille: Hog-nosed snake. Waterloo Farm, on Monie Creek, *Philip Wolle*; McCauley, 1945, Map 13 indicates Crisfield and Dames Quarter.

13. *Opheodrys aestivus* (Linnaeus): Rough green snake. Waterloo Farm, *Philip Wolle* (18–24 inches long).

14. *Coluber c. constrictor* Linnaeus: Black racer. Waterloo Farm on Monie Creek, *Philip Wolle* (48 inches long); McCauley, 1945; Conant, 1945.

15. *Elaphe guttata* (Linnaeus): Corn snake. Waterloo Farm on Monie Creek, *Philip Wolle*.

16. *Lampropeltis getulus getulus* (Linnaeus): King snake. Westover, McCauley, 1945; Waterloo Farm, *Philip Wolle* (both varieties seen with white or yellow bands, 47 inches long).

17. *Natrix sipedon sipedon* (Linnaeus): Common water snake. McCauley, 1945; Waterloo Farm on Monie Creek, *Philip Wolle*.

18. *Thamnophis sauritus sauritus* (Linnaeus): Ribbon snake. McCauley, 1945, along the Pocomoke River in the southeastern part of the county.

19. *Thamnophis sirtalis sirtalis* (Linnaeus): Garter snake. Waterloo Farm on Monie Creek, *Philip Wolle* (4 specimens caught).

20. *Ancistrodon contortrix mokeson* (Daudin): Copperhead. Waterloo Farm on Monie Creek, *Philip Wolle*, 3 authentic specimens seen, head of one preserved.

21. *Sternotherus odoratus* Latreille: Musk turtle. Waterloo Farm on Monie Creek, *Philip Wolle*.

22. *Chelydra serpentina serpentina* (Linnaeus): Snapping turtle. Waterloo Farm on Monie Creek, *Philip Wolle*.

23. *Terrapene carolina carolina* (Linnaeus): Common box turtle. Waterloo Farm on Monie Creek, *Philip Wolle*.

24. *Chrysemys picta picta* (Schneider): Painted turtle. Waterloo Farm on Monie Creek, *Philip Wolle*.

25. *Malaclemys terrapin terrapin* (Schoepf): Diamondback terrapin. Crisfield, *Reed* 1039–1040; many seen by *Philip Wolle* at Crisfield; McCauley 1945, cites Crisfield (*McCauley* T46) and Deal's Island (*McCauley* T45).

POROSITY DETECTION IN PLATED COATINGS

Pores and other flaws seriously impair the quality of industrially produced electroplated coatings, diminishing their effectiveness as protective coatings for metals. Until now it has been difficult to estimate the relative merits of electrodeposits since no method of determining the gravity of defects was available. Recently, however, the National Bureau of Standards has developed a non-destructive procedure for ascertaining both the size and position of pores.[1] The method involves photographing an electroplated specimen exposed to radiation.

In earlier research, a technique applicable to plated coatings that have been removed from the basis metal was developed by the Bureau.[2] However, the likelihood of stripped-coating porosity differing from adherent-coating porosity led to further investigation of the problem. The present work was carried out for the American Electroplaters' Society by F. Ogburn of the Bureau staff and Margaret Hilkert of the Society's research fellowship at the Bureau.

In determining the location and size of pores, the specimen, a flat sheet of plated metal a few thousandths of an inch thick, is placed on a photographic film with the coating against the film emulsion. The assembly is held in a cardboard cassette, and the basis-metal side of the specimen is exposed to X-rays or radiation from a radioactive material. To insure good contrast, the X-radiation used must be soft. This requirement of low-energy X-rays limits the thickness of the basis material to several thousandths of an inch, since thicker metal absorbs too much of the X-ray beam and requires too long an exposure time. Radioactive iron, nickel, or cobalt held against the plated specimen in a cassette are also adequate sources of radiation.

After a suitable exposure time the film is removed and developed, satisfactory radiographs result from a 3- or 4-min exposure to an X-ray machine, and from a 24-hr exposure to 1μc of radioactivity. Wherever a pore existed in the coating, a black spot appears on the developed film. A fine-grain industrial X-ray film gives the most readable radiograph.

This radiographic method detects pits, voids, and inclusions in the coating to the order of 0.001 in. in diameter. Discontinuities in the basis metal may also be determined by radiographing the metal before plating.

[1] *The nature, cause and effect of porosity in electrodeposits, II. Radiographic detection of porosity in electrodeposits*, by F. Ogburn and M. Hilkert, Ann. Tech. Proc. Amer. Electroplaters' Soc.: 256. 1956.

[2] *The nature, cause, and effect of the porosity in electrodeposits*, by F. Ogburn and A. Benderly, Plating **41**: 168. 1954.

FIRE DETECTION IN AIRCRAFT ENGINE SPACES

When fire breaks out in an aircraft engine space, it must be detected and quenched within seconds to avoid serious damage or possible loss of life. To provide design specifications for reliable, fast-acting fire detectors, the National Bureau of Standards has been studying flame characteristics that might be applied to aircraft fire detection systems. Results of this work indicate that reliability could be greatly increased by a system that would not respond unless several intrinsic properties of a flame were all present at the same time. These properties are (1) characteristic rate of increase of radiant flux, (2) sufficient level of radiant flux in the required spectral region, and (3) characteristic frequency of flicker. The investigation was undertaken for the Wright Air Development Center by W. F. Roeser and C. S. McCamy of the Bureau's fire protection laboratory.

Too often in the past, frequent false alarms have undermined the airman's confidence in his fire detector, causing him to hesitate or neglect to take action when an alarm sounded. In some instances fires were not detected or were detected too late. Flight experience and fire tests under simulated flight conditions have clearly indicated that to be effective, a fire detector must invariably respond if, and only if, there is a fire and it must do so as quickly as possible.

Detectors are required to discriminate between fires and other phenomena under the most adverse environmental conditions, including temperatures from −65° to over 500°F, wind speeds over 500 mph, rain, hail, fog, salt spray, dust, oil, grease, fungus, fumes, vibration, and extreme pressure changes. A detector designed to respond to the radiant energy from flames for example, must discriminate between flames and sunlight, lightning, gun-fire, or beacons. The detector must survive a fire with flame temperatures over 2000°F so that it can indicate that the fire is out and be ready to detect another fire a short time later. The aircraft designer demands that detectors have the least possible size and weight.

A survey of existing or proposed systems revealed a number of ingenious applications of various physical principles. Radiant energy detectors seemed the most promising because a single detector can monitor a large space. However, for development of improved designs, more fundamental data were needed on the characteristics of flames involved in aircraft engine fires. Therefore, a study was undertaken at the National Bureau of Standards of the radiation and flicker of flames.

FLAME SPECTRA

The more important flammable materials found in aircraft engine spaces include such liquid hydrocarbons as engine fuel, lubricating oil, and hydraulic fluid. In a typical engine fire involving these flammable liquids, oxygen diffuses into the flames from the surrounding atmosphere, producing a "diffusion flame" which emits essentially the same continuous spectrum for each of the burning liquid hydrocarbons. Experiments were performed which showed that various aircraft fuels premixed with air before burning produced nearly identical spectra except for the lead lines in the spectra of leaded fuels. As a result of these spectrometric studies it was concluded that for the design of radiant energy detectors the same spectral region would be suitable for all fuels likely to be involved.

RADIATION MEASUREMENTS

The radiant intensities of the flames of various fuels were measured in five wavelength intervals from 0.24 micron in the ultraviolet to 2.5 microns in the infrared. To measure the fluctuating radiant intensity in all parts of the spectrum simultaneously, photoelectric detectors were used with suitable filters and the output signals were recorded on a multichannel recording oscillograph. A radiation-pyrometer detector with appropriate filters measured the radiance of flames in several infrared regions extending to 9.5 microns.

The investigation showed that flames of the type likely to occur in engine spaces emit energy throughout the spectrum but emit far more in the near infrared than in any other wave-length region. Some parts of the spectrum were found to be unsuitable for use in fire detection. The strong absorption of radiant energy by oil, grease, and soot in the visible and ultraviolet parts of the spectrum would prevent reliable detection of energy of those wavelengths. The visible part of the spectrum is also considered undesirable because of the high intensity of sunlight and skylight in that region. The most suitable part of the spectrum for fire detection therefore appears to be the near infrared.

The characteristics of various window materials were considered with respect to ambient conditions and their effects on discrimination. Of the materials capable of withstanding the ambient conditions expected, fused quartz appears to be the most satisfactory since it transmits well in the infrared out to about 3.8 microns. Moreover, it transmits a somewhat larger percentage of the energy from flames than from a hot metal background having the same radiance as a flame, thus providing a measure of discrimination between these sources.

INCREASE IN RADIATION

Although the engine radiance may approach that of a flame, the engine takes a much longer time to heat up than the fuel vapors take to burst into flame. Measurements show that the flames to be expected in accidental fires in engine spaces reach full intensity about a quarter of a second after ignition, while the engine takes over a minute to warm up. This difference in rate of increase of radiation provides another distinguishing feature for detection purposes.

FLICKER MEASUREMENTS

A high level of radiant flux or a rapid rate of rise could be caused by events other than fires. One of the recognized attributes of flames is their natural tendency to flicker—to produce a fluctuating radiant intensity. This effect occurs simultaneously in all parts of the spectrum studied. The nature of flicker was observed with high-speed motion pictures and electronic wave analysis of the output of photoelectric detectors.

The motion picture measurements indicate that variation in projected flame area rather than variation in radiance accounts for a large part of the flicker of flames. Electronic wave analysis provided flicker amplitude distribution curves for the various flames studied. In many cases, these curves have a sharp maximum at some frequency between 3 and 15 cps. The ratio of the rms flicker amplitude to the average radiant intensity for various flames ranges from about 0.1 to about 0.4 for burning liquids. These results indicate that flicker provides another valuable distinguishing feature for detector design. Since moving engine parts or other periodic phenomena might cause fluctuations in the radiant flux, flicker was not recommended for use alone as a fire detector, but rather in combination with the characteristic rate of increase of radiant flux and sufficient radiant intensity in the right spectral region.

For further technical details, see *A five-band recording spectroradiometer*, by C. S. McCamy, Journ. Res. NBS **56** (5). May 1956 (RP 2678); *Principles of fire detection in aircraft engine spaces*, by W. F. Roeser and C. S. McCamy (may be purchased from the Office of Technical Services, Department of Commerce, Wasington 25, D. C., price, $3).

GENETICS IN THE SERVICE OF MAN

With recent developments in genetics, science now actually is creating new species of plants. It has not yet succeeded in creating a new species of animal, although this is theoretically possible by the same methods. The fact remains, however, that walls in nature have been broken down which a few years ago were considered impregnable except through very long natural processes. This revolutionary advance is described by Dr. Bentley Glass, professor of biology at The Johns Hopkins University, in the most recent Annual Report of the Smithsonian Institution.

"For a long time now," Dr. Glass says, "mankind has substituted for the selection of nature his own artificial selection of whatever chance mutations appeared in his domestic animals and cultivated plants and which seemed to him to be desirable. It is thus that all the progress in plant and animal breeding has been made, from the day the first animal was tamed and the first seed planted to the beginning of our own century. What geneticists are now enabled to do is merely to speed up this process a thousandfold and to control and direct it more effectively."

Actually, he says, the first man-made species was created by a Russian geneticist, G. D. Karpechenko, nearly 30 years ago. Karpechenko crossed two different genera of plants, cabbage and radish. The hybrid, as was to be expected, was completely sterile. He then succeeded, by techniques then in their infancy, in doubling the chromosomes (strings or bundles of hereditary units, or genes, such as are carried in the nuclei of every plant and animal cell). As a result he obtained in the next generation a perfectly fertile form which he named *Raphanobrassica*. This could be roughly translated as "rabbage."

The new plant species, as was also to be expected, was worthless. It combined the prickly, inedible leaves of the radish with the miserable root system of the cabbage. But this was only a beginning. The doubling of chromosomes now can be accomplished almost at will by means of the drug colchichine, extracted from the European crocus and long used as a remedy for gout. Thus geneticists can experiment with all sorts of crosses between species and even genera and some of these may be expected to be quite valuable.

"There is," Dr. Glass says, "no difficulty in controlling the amount of genetic intermixture by performing, on the one hand, the desired crosses, and on the other by isolating and otherwise preventing intermixture, just as man in the past has controlled the interbreeding between different breeds of dogs or cats." Still, he stresses, the planned breeding of man still is far in the future, if it ever can be achieved.

"The basis of effective eugenics," he says, "must include not only an understanding of evolutionary processes and the power to control them; it must include also a far wider knowledge of human genetics than now exists, and the ultimate consideration by society of many questions of human values." There are difficulties in the way, he emphasizes, which are likely to be overlooked. It has been suggested, for example, that it would be possible to eliminate hemophilia, the bleeding disease so common in European royalty, which is passed on in the female line but manifests itself only in the male line.

It is possible that by controlled matings the incidence of this and other hereditary maladies could be greatly reduced. The fact remains that new mutations which result in the tragic malady of hemophilia occur at the rate of about 1 in 50,000 individuals per generation; "that is," he says, "in a population of 50,000 persons 1 person has a gene for hemophilia which was not inherited from either parent, but instead arose by mutation from a corresponding gene for normal blood clotting. Hence, unless one could somehow prevent mutation to it from occurring, no measures can be successful in eradicating an undesirable gene from the population. At best, its frequency can be reduced to the level of the rate of mutation to it." Hence the lowest limit of hemophilia is set by mutation at 1 in 50,000 males.

Mutations, both good and bad, can be produced by ionizing radiation and by chemicals, Dr. Glass points out. These, however, are altogether too potent to be used on a human population. Only one change in 500 to 1,000 improves fitness to live in a given environment. The rest are bad. The majority will be so-called recessives which may remain hidden in the germ plasm for generations—all the time accumulating to a level when some of them will be brought together in mating and show up in some of the offspring.

This might well be disastrous, he stresses, if the present population of the world were broken up into small units—such as might result from another major war. The present trend, with advances in transportation and communication, seems to be toward a unification of races and peoples, a condition in which the inherited recessives have a greatly reduced chance of coming to the surface. In restricted populations, probably with considerable inbreeding, this chance would be greatly increased.

RIVER BASINS ARCHEOLOGY

Evidence suggesting human occupation in the Upper Hell's Canyon region on the Snake River over a period in excess of a thousand years was obtained during the recent field season by archeologists of a River Basins Survey party from the Smithsonian Institution, working in areas to be flooded by the Brownlee and Hell's Canyon reservoirs.

Under the direction of Dr. Warren W. Caldwell and George L. Coale, the party, supported by funds provided by the Idaho Power Co., made an interesting series of excavations in rock shelters, refuse deposits, and village areas. Most of the material recovered came from four habitational sites, two on the Oregon side of the Snake at Robinette and two on the Idaho side at Big Bar. The majority of the artifacts found indicate that these sites date from the late prehistoric period and the early period of European contact, but at two of them there were items coming from much earlier horizons. The general picture, according to Smithsonian archeologists, is that of an early expansion of Great Basin cultural features into the Northwest and their later replacement by a

more dynamic cultural pattern working upstream form Mid-Columbia centers.

The artifacts collected during the digging show that the people had a basically hunting-gathering type of economy. They include large numbers of projectile points, knife blades, scrapers, and other stone tools. The implements were found in association with quantities of deer and elk bones, indicating marked dependence on the hunting of large game animals. The presence of milling stones shows that there was some utilization of the many plant foods available in the area. Implements associated with fishing are for the most part lacking, but the abundance of freshwater mussel shells in kitchen middens suggests that aquatic food had a place in their diet.

At an open camp site on Big Bar several housepit depressions were still evident and one of them was excavated. A saucer-shaped floor measuring approximately 25 feet in diameter, with a depth of about one foot near the center, was uncovered. The depression probably served as the base for a light, possibly brush, superstructure. There was no evidence of a more substantial, permanent-type dwelling. Copper strips found slightly above the floor level are a good indication that type of structure was still in use at a time when European trade goods were beginning to filter into the region.

When the first Europeans arrived the area was inhabited by a band of the Shoshoni known as the "Mountain Sheep Eaters." They were a seasonally nomadic group of Indians who subsisted mainly by hunting and gathering activities. They were last known to visit the region regularly in the 1880's, and their survivors now live mostly on reservations in Idaho and Oregon.

SOLAR CORONA

The corona—faint, tenuous envelope of the sun which extends outward for about 2 million miles from the star's surface and has a temperature of at least a million degrees centigrade—holds the key to many mysteries of solar phenomena. This is the conclusion of Sir Harold Spencer Jones, former Astronomer Royal of Great Britain, in the most recent annual report of the Smithsonian Institution. Especially is this true of the radio wavelength radiations from the sun at irregular intervals which cannot be accounted for by the known temperature of the solar surface. The ionosphere, or electrified layer of the earth's upper atmosphere from which radio waves are bounced back to earth, is created by radiations from the sun close to the X-ray wavelength. The astronomer explains:

> Theoretical investigations have led to the conclusion that the observed degree of ionization [stripping of outer electrons off atmospheric atoms] in the E-layer of the ionosphere requires radiation whose intensity is of the order of 100,000 times that of a black body of a temperature 6,000° K. [that of the sun's visible surface]. This high intensity of radiation . . . is readily accounted for by the high temperature of the corona.

There has been much speculation about the mechanism by which the high temperature of the corona is maintained. One theory attributes it to the infall of interstellar dust, the kinetic energy of the dust particle being distributed as heat throughout the coronal matter. Another view is that it is produced by magnetic processes, associated with magnetic fields on the sun and the emission of high-speed particles, the corona possibly being heated by electric currents flowing through it. A third suggestion is that sound waves are generated by the turbulent motion of gases in the sun's atmosphere and that as these waves move outward into more tenuous regions they develop into shock waves, which produce the high temperature of the corona. . . .

> The increase in effective temperature from centimeter to meter wavelengths that is required to account for the observed intensities of radiation on radio wavelengths from a quiet sun, can be explained on the assumption that the centimeter waves originate in the level just above the visible surface of the sun, while the meter waves [required for ionospheric ionization] originate at a much greater height, where the temperature is much higher. If these latter waves were generated near the surface of the sun they would be absorbed an would be unable to escape into space.

At the bottom of all cosmic order lies the order of mathematics, the law that twice two is always four.—P. CARUS

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